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U.S. DEPARTMENT OF AGRICULTURE

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2019 SPECIAL EDITION
DEPARTMENT OF AGRICULTURE

Juan Gonzales tends to cucumbers at a farm incubator for the Agriculture and Land-Based Training Association in Salinas Valley, Calif.

SHAWN LINEHAN PHOTOGRAPHY

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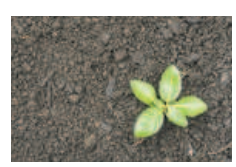

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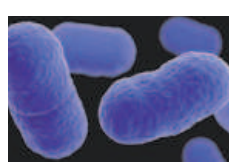

JENNIFER OOSTHUIZEN/CDC

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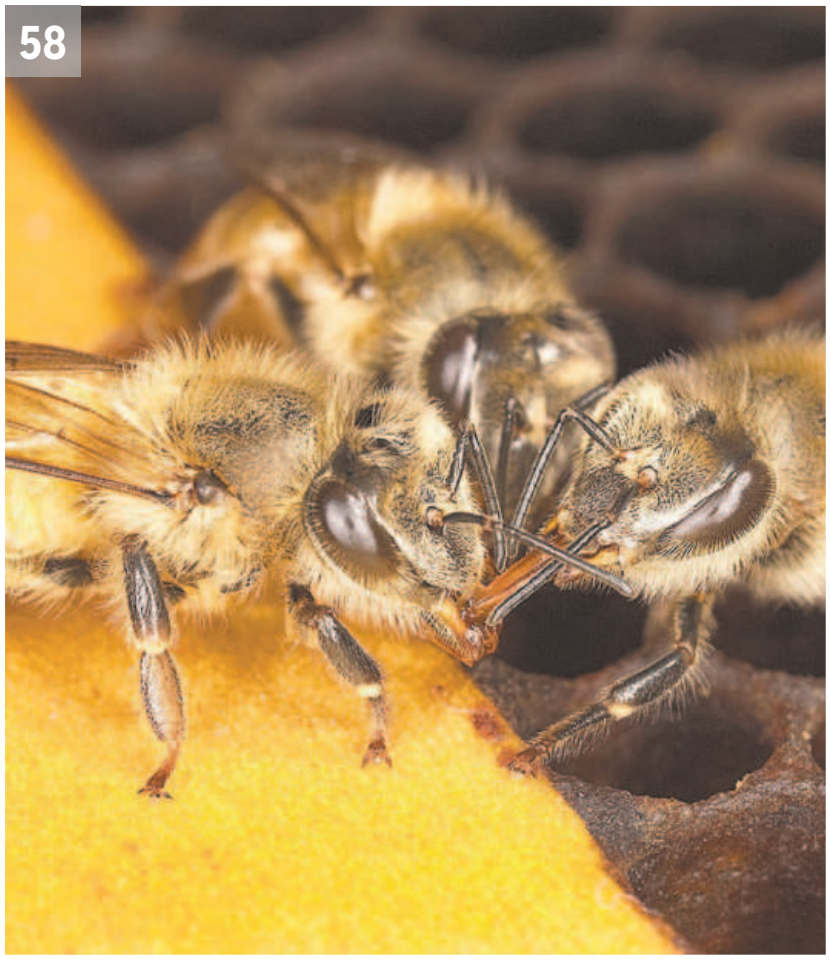

STEPHEN AUSMUS/USDA

ON THE COVER
Minnesota soybean field during early morning sunrise.
PHOTO BY GETTY IMAGES

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TECHNOLOGY & ADVANCEMENTS

MATT VODRASKA

PROVIDED BY BENSON HILL BIOSYSTEMS

EDUCATION & CAREERS

ON THE FARM

USA TODAY NETWORK

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ISSN#0734-7456

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LANCE CHEUNG/USDA

Firmly Planted

It's been a tough year for agriculture, but seasoned veteran Sonny Perdue is up to the task

By Brian Barth

LAST YEAR WAS AN incredibly busy year for Secretary of Agriculture Sonny Perdue. He traveled the country nearly nonstop to meet with farmers and other constituents, and there was plenty to talk about.

A record year of storms, fires and flooding in 2017 left many producers, especially those in the southeast and western states, dealing with devastating losses. The 2017 Wildfires and Hurricanes Indemnity Program is providing $2.36 billion through the USDA's Farm Service Agency to aid recovery.

Summer and fall of 2018 brought another swath of natural disasters, and while the damage to agricultural operations was not as severe, thousands of American citizens were displaced. The USDA played a major supporting role through its Food and Nutrition Service, providing meals to tens of thousands of families after hurricanes Michael and Florence. Perdue made multiple visits to the areas affected by these back-to-back weather events to survey the damage and offer support to local officials.

The outlook for the agricultural economy has remained fairly bleak, with a 12 percent drop in net farm income estimated for 2018, continuing a slide that began in 2012. Dairy income, down 41 percent in 2018, was particularly hard hit. A trade war with China, the biggest buyer of U.S. soybeans, leaves Perdue with the tough task of rallying support for President Donald Trump's trade policies in the agricultural community. Perdue welcomed the White House's authorization last July of up to $12 billion in aid for farmers affected by retaliatory tariffs.

On a more uplifting trade note, Perdue chalked up a big win for America's agricultural exporters: the signing of the United States-Mexico-Canada Agreement (USMCA) to replace the North America Free Trade Agreement (NAFTA) in November. This is a boon for many sectors of the agricultural economy, but is particularly important for the nation's beleaguered dairy producers because it eliminates aspects of the Canadian supply management system that had long prevented American dairy farmers from competing in that market.

And just before the end of 2018, Perdue celebrated the signing of a new farm bill, which was hailed as a success by agriculture groups across the spectrum, from tiny organic producers to the biggest commodity growers. Some of the more unique inclusions in the 2018 Farm Bill were funding to help farmers transition to organic practices, which will enable more growers to take advantage of the cost premiums associated with the organic label; and the legalization of industrial hemp, which will allow farmers to capitalize on the immense demand for THC-free CBD oil — a market expected to grow to $20 billion by 2022.

Perdue also instituted a new feature at the USDA: "Tell Sonny," an online portal for giving feedback on how the agency is serving its constituents. It's just one of many ways the secretary is working to make the agency more responsive to producer needs. It's a theme he spoke passionately about during a recent interview with USA TODAY, in which he also addressed his strategies for dealing with the unprecedented challenges facing American agriculture. And Perdue is quick to remind people that the USDA is charged with not only protecting and supporting farmers, but rural prosperity as a whole — and, for that matter, anyone who eats.

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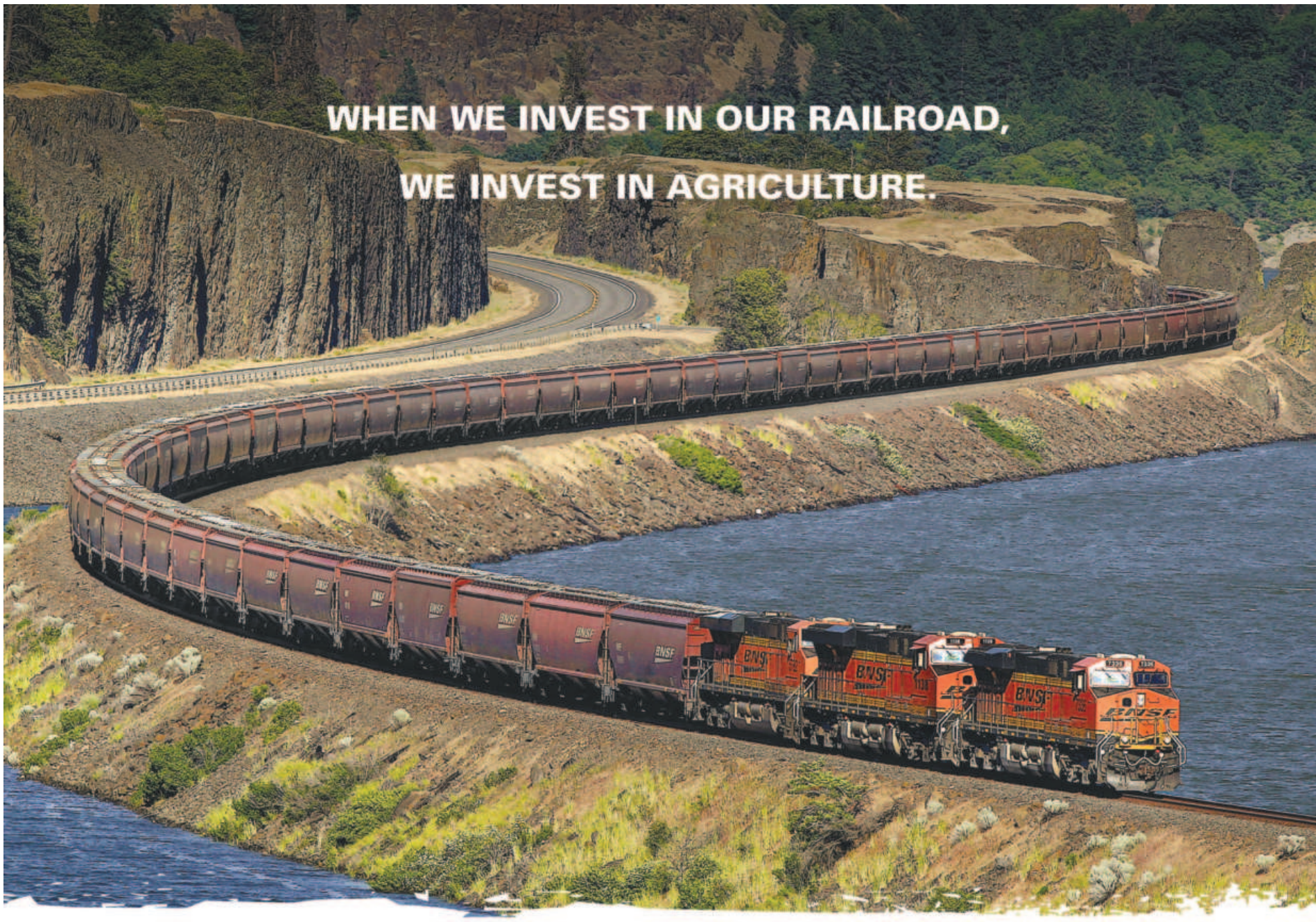

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NEWS & BUSINESS

LANCE CHEUNG/USDA(3); PRESTON KERES/USDA

Perdue spent time in 2018 wrapping up his "Back to Our Roots" rural tour, where he gathered input on the 2018 Farm Bill and talked to producers about increasing prosperity.

Q How are you feeling about the 2018 Farm Bill?

PERDUE: I was very pleased to see the farm bill pass both chambers of Congress with bipartisan support and signed into law by President Trump. This farm bill maintains a strong safety net for the farm economy, invests in critical agricultural research, and will promote agriculture exports through robust trade programs. While we would have liked to see more progress on work requirements for SNAP (Supplemental Nutrition Assistance Program) recipients and forest management reforms, this agreement does include several helpful provisions, and we will continue to build upon these through our authorities.

Last year you established the Interagency Task Force on Agriculture and Rural Prosperity, issuing a report with more than 100 recommendations. What progress has been made?

This administration is committed to helping rural America succeed in the 21st century economy. In 2018, USDA invested in:

- High-speed e-connectivity for more than 45,000 rural homes and businesses.
- Modernized rural electric infrastructure for more than 7 million customers.
- Water and wastewater infrastructure for nearly 3 million rural customers.
- Community infrastructure, including streets, transportation, aviation, ports and water and storm water resources for 1.2 million rural Americans.
- Essential community facilities projects such as schools, libraries and municipal centers serving 9.3 million people.
- Health care projects serving 5.5 million rural Americans.
- Innovative distance learning and telemedicine projects to help 4.6 million rural Americans access health care, education and job training opportunities.

"I'm proud that the work we're doing is positively benefiting the people of America's agriculture industry."

– SONNY PERDUE, agriculture secretary

Do you feel that quality of life in rural areas has begun to improve?

President Trump's policies have resulted in a booming economy that is benefiting all Americans, including those in rural areas. I have visited 48 states and two United States territories since becoming secretary of agriculture, and I can report that the farmers and ranchers I have met appreciate President Trump's efforts on their behalf. As he has said many times, President Trump loves America's farmers and ranchers and will keep working and fighting for them.

The USDA has pledged $12 billion to support farmers impacted by retaliatory tariffs. Is it enough?

America's agriculture commodities were targeted by illegal retaliatory tariffs, causing direct harm to our farmers and producers. That is why President Trump launched our trade mitigation program, which authorized $12 billion in purchases and payment to farmers, in an effort to reduce their losses. While this money will not make farmers whole, it will help them plan appropriately for next year's growing season.

How do you see the trade war playing out at this point with regards to agriculture? Are media stories about the effects overblown? Or has the full magnitude not yet hit?

The current trade situation is an example of short-term pain for long-term gain, and American farmers understand that. President Trump is committed to getting trade deals that put America first and his strategy is working. A renewed USMCA, a new KORUS agreement (United States-Korea Free Trade Agreement), and the continued progress with Japan, can lead to further deals with other trading partners like the European Union and China. I thank President Trump and our U.S. trade representative, Ambassador (Robert) Lighthizer for their perseverance, leadership and hard work.

Are you satisfied with USMCA and the deal that was struck for agriculture?

USMCA was a win for American farmers. Notably, this agreement eliminates Canada's unfair "Class 7" milk pricing scheme and cracks open additional access to U.S. dairy into Canada. With NAFTA, the U.S. had zero non-tariff access, now we have close to 4 percent, which is higher than what was negotiated with the Trans-Pacific Partnership. USMCA imposes new disciplines on Canada's supply management system, preserves and expands critical access for U.S. poultry and egg producers and

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SARAH MARQUART/USDA

In November, Perdue toured a pistachio orchard at Strain Ranches in Arbuckle, Calif., and held a roundtable with area producers.

finally addresses Canada's discriminatory wheat grading process to help U.S. wheat growers along the border become more competitive.

People often forget that the U.S. Forest Service is a division of the USDA. It is one that has received attention of late due to record-breaking wildfires. How is the Forest Service's strategy for wildfire management evolving?

USDA's strategy to fight future forest fires is to work with our federal, state and local partners to actively manage our nation's forests. Well-groomed, well-managed forests do more to preserve our nation's forests than allowing fuel to build up after years and years of litigation and mismanagement. We have to acknowledge that some of the litigation that well-meaning people have brought against our common-sense forest management practices has contributed to these massive forest fires. We need to get out of the litigation business and into the mitigation business.

What are you most proud to have accomplished thus far in your term?

I'm proud of so many things we've done here at USDA that it's hard to choose just one. Having visited 48 states, two territories and six foreign countries in a little over a year and a half, I'm proud that the work we're doing is positively benefiting the people of America's agriculture industry. Getting out of Washington, rolling up my sleeves and spending time with my constituents really is one of the best parts of the job.

DARIN LEACH/USDA

Perdue touts multiple initiatives that the USDA accomplished in 2018, including modernizing rural electric infrastructure for more than 7 million customers.

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Pick Your Own

Seasons bring fresh revenue opportunities for producers, farmers

By Larry Bleiberg

AS INTEREST IN EATING healthy and fresh foods continues to grow, more family farms are transforming into "agritainment" areas, welcoming visitors to pick produce and enjoy rides and attractions. "You're getting exercise, getting outdoors and eating a lot healthier," said John Slemmer, who runs Pickyourown.org, which lists about 10,000 farms in 20 countries where visitors can harvest their own fruits and vegetables. Here are a few across the U.S. to visit:

MATT VODRASKA; CHRIS VODRASKA

RITTMAN ORCHARDS

Doylestown, Ohio

Although many Ohio farms welcome visitors, Slemmer particularly likes this one near Cleveland. "They're just super nice people, kind of like family." Pickers are welcome to harvest strawberries, red and black raspberries, blueberries and apples. Some visitors just come for the extensive farm market, cider and live music.

▶ *rittmanorchards.com*

NIKKI STUDT

UNDERWOOD FAMILY FARMS

Moorpark, Calif.

With several locations, this Southern California farm has become an agricultural force. Dozens of pick-your-own options range from fava beans and squash blossoms to kohlrabi, and a platoon of pull wagons are available to haul in your harvest. There are also tours and animal shows. "This is one of those places people rave about," Slemmer said. "They really make a fun day out of it."

▶ *underwoodfamilyfarms.com*

WEBB RANCH

Portola Valley, Calif.

This nearly century-old family farm near Stanford University offers organic berries, including olallieberries, boysenberries and marionberries. "If you're not from the West Coast, you'll never see these berries in a store," Slemmer said. Stop by the website for a how-to-pick video, and then head to the farm for horse-riding lessons.

▶ *webbranchinc.com*

SOUTHERN BELLE FARM

SOUTHERN BELLE FARM

McDonough, Ga.

Bite into a fresh Georgia peach at this 330-acre property south of Atlanta, and you'll never look at grocery store fruit the same, noted Slemmer. "Unless you go to a farm, you'll never get a real peach. It's supposed to be soft and juicy." Along with the peach orchard, there are blueberries and strawberries to pick, and farm animals on display. A country market also sells fresh pie.

▶ *southernbellefarm.com*

BELKIN FAMILY LOOKOUT FARM

BELKIN FAMILY LOOKOUT FARM

Natick, Mass.

Operating since 1650, Lookout Farm is one of the oldest in the country, but it's tough to know what the original settlers would make of the city families filling fruit baskets and lining up for train rides. "It's a big operation," Slemmer said. Summertime picking options include strawberries, and then peaches and early apples in August, followed by plums and nectarines. And a family-friendly taproom serves farm-crafted hard cider, beer and food pairings.

▶ *lookoutfarm.com*

VISIT LOUDOUN COUNTY

GREAT COUNTRY FARMS

Bluemont, Va.

When Washington, D.C., tourists need a break from monuments and museums, they can head about 60 miles west, where summer visitors can pick cherries, plums and berries on this family farm. And come August, the "great potato dig" lets kids unearth their own carbs. Families also enjoy wagon rides, a jumping pillow and a catch-and-release fishing pond. "They've got a lot there — all the stuff kids like. And it goes from spring right into late fall," Slemmer said.

▶ *greatcountryfarms.com*

STADE'S FARM AND MARKET

McHenry, Ill.

This Chicago-region farm shows why the Midwest is famous for its agriculture. Its you-pick season kicks off with strawberries in mid-June, continues with raspberries in July, and adds summer vegetables like green beans, tomatoes and sugar snap peas in August. "It's in the heart of the country's breadbasket," Slemmer said.

▶ *stadesfarmandmarket.com*

REMLINGER FARMS

Carnation, Wash.

Slemmer said there's a simple reason to visit this Seattle-area farm: rhubarb, which is available in the market and prepared in an on-site restaurant. "If you've never had a rhubarb strawberry pie with a crumb top, you've never lived." Visitors also come for berry picking and a family fun park with more than 25 attractions, including a steam train, farm-themed roller coaster and a toy canoe river.

▶ *remlingerfarms.com*

BLESSINGTON FARMS

Simonton, Texas

The hydroponic system at this farm west of Houston grows berries in vertically stacked containers, so visitors don't have to bend over to pick. The farm's extensive play area offers a fishing pond, tire mountain, tug of war and more. "It's a massive farm playground," Slemmer said.

▶ *blessingtonfarms.com*

Kameron Donaldson holds a clump of plant material filled with worms and nutrients on his family farm in Peru, Ind. He's been working to improve his soil health for the past several years.

MICHELLE PEMBERTON/THE INDIANAPOLIS STAR

GOOD DIRT

YOUR PRODUCE IS LESS NUTRITIOUS THAN IT WAS 70 YEARS AGO BECAUSE SOIL HEALTH HAS DECLINED. SOME FARMERS ARE WORKING TO CHANGE THAT.

By Carrie Blackmore Smith and Emily Hopkins

THERE IT SITS — IN all its green glory — in the produce section of your grocery store: broccoli, one of the most nutritious vegetables on the planet. But 70 years ago, it contained twice the amount of calcium on average and more than five times the amount of vitamin A — and the same could be said for many of our fruits and vegetables.

One reason lies in the soil and how Americans farm it.

Over the past two centuries, U.S. population growth and farming have stressed and degraded our dirt quality. Our soil is not as alive as it once was, and experts say that's a problem.

It's a complex issue, and there are various factors at play, but studies through the years draw a direct line back to American farms. More and more farmers are recognizing that they are part of the problem — one that extends beyond their acreage and also affects the water quality in our lakes, rivers and oceans downstream.

Slowly, a soil health movement is spreading across the Midwest and other parts of America. Farmers are modifying the way they farm, changing crop rotations and adding cover crops — plants grown primarily to restore fertility to the soil. They're finding ways to use less fertilizer, which is linked to decreased soil health and water degradation.

"This has an impact on everybody who eats," said Eileen Kladivko, a professor of agronomy at Purdue University.

Farmers in states like Indiana are leading the way, and experts say the movement is on the cusp of mainstream adoption — although much still stands in the way.

A troubled agricultural past

In the 1930s, dirt was top of mind in America. Much of the country was experiencing a crushing series of droughts that lasted eight years. Poor land management and over-cultivation gave rise to the Dust Bowl. In those days, it was typical to plow a field to a pulverized, fine dirt before planting. So, when the extended dry spell hit, soil became loose and was swept away by

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GETTY IMAGES

Farmer Richard Stewart plants cover crops to maintain soil health and relies on trees and native plants to keep runoff from polluting water.

> **“It’s better to just take care of the land and it’ll take care of you. But there is a cost to getting that land where you want it to be.”**
>
> – KAMERON DONALDSON, Indiana farmer

intense dust storms that blotted out the sun.

Farmers couldn’t grow food. Millions were forced to leave their homes to find work. The ordeal resulted in the adoption of the uniform soil laws and the creation of the Soil Conservation Service, today referred to as the Natural Resources Conservation Service (NRCS), and was the birth of the modern-day soil health movement. At the time, the effort focused on erosion or, simply, how to keep the dirt in place. Still, farmers continued to harm the soil, unintentionally, said Harold van Es, a professor of soil and water management at Cornell University.

In the 1950s, farmers began using synthetic fertilizers, which weren’t bad in and of themselves, said van Es, but they allowed for a new way of farming in America that would often further degrade the soil. And many farmers stopped raising livestock for the manure and focused only on cash crops, including corn and soybeans, which are used in many products.

Farmers began producing one or two crops, planted year after year. Over time, the combination of these practices lowered the biodiversity of the soil. Healthy soil should be teeming with microbes and worms and rich with decomposed organic matter.

Today, the government budgets billions of dollars — $6.7 billion in 2017 alone — for conservation through the Farm Bill. That funding goes to agencies that include the NRCS, which offers financial and technical assistance to farmers to adopt practices like cover crops.

For a century, farmers have been using cover crops. Grains, grasses or legumes grow during the fall and winter, keeping the soil safe from erosion, building up nitrogen levels, suppressing weeds, retaining water and restoring nutrients. In the spring, they are plowed or tilled. Used regularly over time, this regimen will lead to improved soil structure.

“I think we’ve reached a tipping point in terms of awareness and experimentation,” van Es said. “In terms of adoption, we simply need more farmers to start doing it.”

Changing how we farm

Richard Stewart manages Carriage House Farm in Ohio’s western Hamilton County. The 163-year-old farm has been owned by his family for five generations.

His goal is to stop conventional farming — growing corn and soybeans for animal feed and export — and instead only grow things that people eat. His family converted about 60 acres of its 300-acre farm to produce fruits, vegetables, honey and a line of vinegar.

Stewart is paying close attention to the soil. He’s learned, for example, to plant a cover crop of mustard before he grows a crop of potatoes. The mustard keeps away the Colorado potato beetles, which love potatoes but not mustard. He makes sure there is a healthy strip of trees and native plants between his fields and the Great Miami River because he wants to keep his soil in place and avoid any runoff that might pollute the water.

“I’ve got kids. My child may be the seventh generation that farms this property, but that is not even a blink in the eye of the history of this planet,” Stewart said. “The Shawnee were people who farmed and hunted this land 3,000 years prior to us, and we’ve taken more nutrients out of the soils than human beings did the last 3,000 years.”

Cover crops involve planting on the field during the offseason, so there’s always something growing. Keeping something growing holds the soil in place, and when the cover crops grow and die they add organic matter, attracting microorganisms, adding nutrients and creating healthier soils. Farmers nationwide are

CONTINUED »

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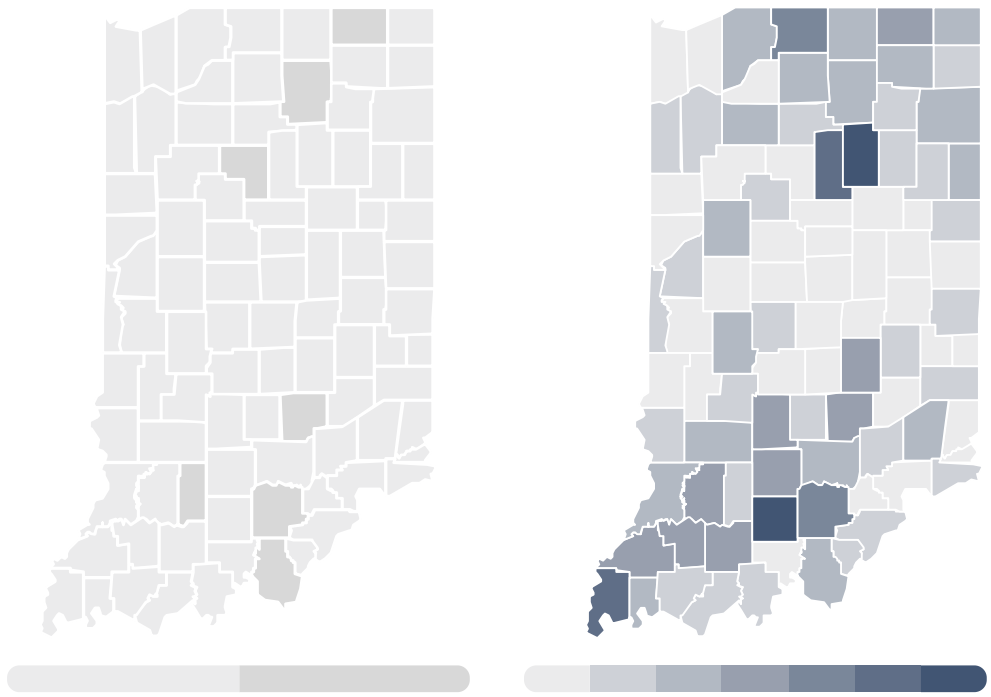
COVER CROP PRACTICE GROWING

From 2011 to 2017, the practice of planting cover crops in Indiana increased more than 450 percent. A county-by-county comparison:



SOURCE: *Indianapolis Star* analysis of U.S. Department of Agriculture county-level data on cover crops. Percentages based on National Agricultural Statistics Service crop data.

Mike Starkey's farm has become a destination for politicians and fellow farmers who are eager to see how he uses cover crops to make his soil healthier.

compelled to improve their soils. Take Indiana, for example, where the number of farm acres sowed with cover crops more than quintupled in just five years. But Indiana still has a long way to go. More than 90 percent of cropland in the state is still farmed without cover crops, according to data compiled by the Indiana NRCS.

It's tough to blame farmers who don't participate. Rising seed prices, irregular weather patterns and talk of tariffs create financial challenges and uncertainty.

Shannon Zezula, state resource conservationist for the Indiana Natural Resource Conservation Service, sees this as part of the reason that last year, for the second year in a row, the percentage of cover crops fell slightly in Indiana.

"Here in Indiana we estimate we've lost about 50 percent of our soil's organic matter," largely in the last 70 years, Zezula said. "How much longer can we continue to farm this way? Many Indiana farmers are seeing the need to reverse that trend."

Breaking into the mainstream

Shefali Mehta is not discouraged. As the executive director of the Soil Health Partnership, a program launched by the National Corn Growers Association in 2014, she saw the soil health movement catching on because more farmers are getting positive results.

The organization helps farmers perform economic assessments in order to understand how they can be more productive and sustainable through different management practices. Together, they consider today's technology, weather and markets to determine methods that will improve the soil, help the environment and also make the farm more profitable.

"Times are tough in all industries, but especially agriculture," Mehta said. "Farmers in the U.S. continue to face headwinds from many directions. However, there are still many reasons to remain optimistic."

Adoption is accelerating, Mehta said. When the partnership formed in 2014, its goal was to sign up 100 farmers in the first five years. It reached that quickly, and now more than 140 farmers in 14

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GRAPHIC: STEPHEN BEARD/THE INDIANAPOLIS STAR; MYKAL MCELDOWNEY/THE INDIANAPOLIS STAR

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Minnesota farmer Mary Jo Forbord reconstructed 380 acres of prairie into fertile earth to plant fruit and vegetables.

states are committed to the program.

Something else is at play, adding urgency for farmers to consider their soils Mehta said. “Climate change in terms of increased weather variability and pressure on the lands is evident. We are focused on how farmers can increase resiliency and be proactive about changes.”

Farmers are dealing with more frequent and unpredictable bouts of drought and flooding, and climate change is affecting our food. Take corn, for example, which can be sensitive to extremes in temperature and precipitation. Warmer summer temperatures can affect corn’s ability to pollinate. The result? Kernels have difficulty growing on the cob.

Humans have a long history of manipulating crops, cultivating strains to withstand certain conditions. We’ve been able to figure out how to keep growing more, even with the heat. But we can only do so much with breeding. Healthier soils can help alleviate the stress of climate change, Mehta said, because they retain more moisture, which can lower the temperature on the fields. And healthier soils store more carbon and release less carbon dioxide — the majority of the world’s greenhouse gas emissions.

Living proof that soil quality makes a difference

Mike Starkey raises corn and soybeans on 2,500 acres in Brownsburg, Ind., northwest of Indianapolis. For the past 13 years, he’s worked to improve his soil, including sowing cover crops between seasons. Starkey said he immediately saved money that he would have spent on equipment, labor and fuel by not tilling his fields. With cash in hand from selling his tilling equipment and help from the state’s NRCS, Starkey invested in cover crops.

Over time, cover crops built up organic matter in his soil, reducing the need to purchase as much commercial fertilizer. The benefits are not just to the farmer, conservationists say, and that’s why there’s a big push for cover crops across the nation. Farm runoff is considered a major cause of harmful algal blooms in our lakes and rivers. It also contributes to the hypoxic, or dead zones, in our coastal waters.

Nitrogen and phosphorus are two nutrients that are integral to water systems. Both foster algae and plant growth, which provide food and shelter for fish and other organisms. But when an overabundance of these nutrients — both also found in fertilizer runoff — gets into the

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water, it leads to toxic algae growth and creates dead zones in areas like the Gulf of Mexico.

Reports of harmful algae blooms increase each year, wreaking havoc on fishing and tourism seasons in Lake Erie, killing animals and causing nausea and rashes among unsuspecting swimmers. In 2017, the low-oxygen algae zone in the Gulf spread a record distance: an area the size of New Jersey. In hypoxic conditions such as these, living things struggle. This affects our fishing industry and the price we pay for food.

That's why Starkey is part of a study to test whether the practices on his farm are improving surrounding water quality. Fields sown with cover crops typically have lower nutrient runoff, but some don't think it's enough to curb the water quality issues facing the nation.

Even with every farmer doing this, states will struggle to come close to meeting nutrient overload reductions, said Trevor Russell, water program director for Friends of the Mississippi River.

"There is a false narrative in the water quality community. It's not (about) doing a better job at what we grow — it's quite literally what we grow," Russell said. "Until what we grow can achieve water quality standards and be economically viable, we're not going to address those problems."

There's pretty much widespread agreement that cover crops help to control erosion and keep the soil resilient. And for some farmers, like Starkey, that's reason enough.

In 2012, when the rest of the country was struggling through the driest conditions since the Dust Bowl, he made it out OK. His corn yields that year were nearly double that of the rest of his county.

Mary Jo Forbord feels as though she's doing her part to farm responsibly. She and her husband run the Prairie Horizons organic beef, fruit and vegetable farm in Minnesota. They plant cover crops, don't use any chemicals and have reconstructed 380 acres of prairie, replacing what farmers before had wiped out.

90%

The amount of cropland in Indiana that goes without cover crops

But Forbord said the cards are stacked against farmers like her and America's food system in general.

From 1800 to 2017, the U.S. population grew from 5 million to 325.7 million people. And today, 25 million are unable to consistently access or afford adequate food.

Yet, more than a quarter of U.S. cropland is used to grow corn, a crop we barely eat. Most of it goes to feeding livestock or our gas tanks. And of the small portion we do eat, most goes into making sweeteners such as high fructose corn syrup. It's a disparity that shows up in our waistlines, as the U.S. continues to lead the world in obesity rates. In the early '60s, about 14 percent of the country was obese, according to the Centers for Disease Control and Prevention. That description now fits 1 in every 3 Americans. "It can be overwhelming to see how much this touches," Forbord said.

Jon Reese grows corn, soybeans and cereal rye grass on his farm in Peru, Ind. After purchasing land with erosion issues, he adopted more eco-friendly practices.

The movement grows

You'll find a type like Jon Reese in almost every county in America. The guy who's always ready to share his knowledge and bring just about anyone to his farm to show you results.

He does that by hosting "field days" on his farm in rural Miami County, Ind. They're like open houses that showcase soil health initiatives. He works the holdouts, offering at a recent event to throw cover crop seed into one farmer's truck and let him borrow his special equipment. "I almost begged him," he said. But the farmer never took him up on the offer.

How will the practice of cover crops spread faster? There's talk about adding soil health labels on our food — to help consumers know whether they're buying from growers who respect the soil. And sustainability groups and corporations are creating metrics to provide individual farms with a stamp of approval.

These are steps forward but need to be closely vetted, said Kladivko. And the common consumer can also play a role, observers and soil health supporters say.

People can do that by paying more attention to where their food comes from, shopping local, asking the farmers who grow food what sustainability measures they are taking and knowing where their politicians stand.

"Indirectly, you can support conservation programs at the federal and state level," said van Es. "You can also trust that organic food is soil-friendly."

Meanwhile, said Kladivko, the soil health movement will continue to spread as it does today, from farmer to farmer. In his corner of the world, Reese's influence is spreading.

Indiana farmer Kameron Donaldson now grows cover crops and is improving the soil on his farm. He has decreased erosion and improved yields of corn and soy. And he's also glad he's going to leave the land better than he found it. "It's better to just take care of the land and it'll take care of you," he said. "But there is a cost to getting that land where you want it to be."

The story was made possible in part by the support of the nonprofit Nina Mason Pulliam Charitable Trust, and by the Institute for Journalism & Natural Resources.

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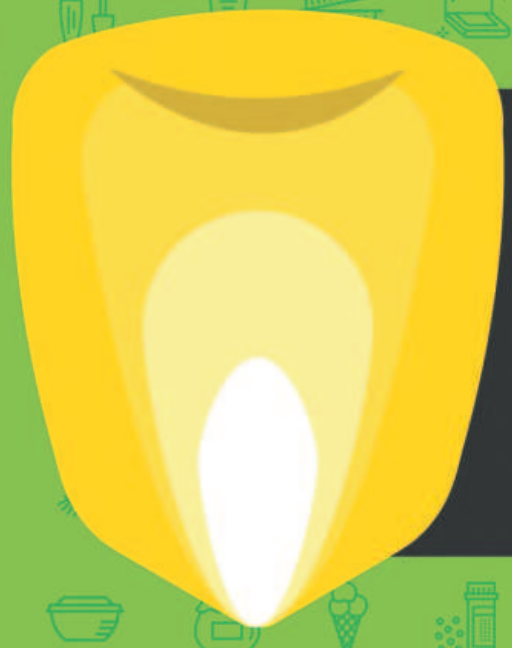

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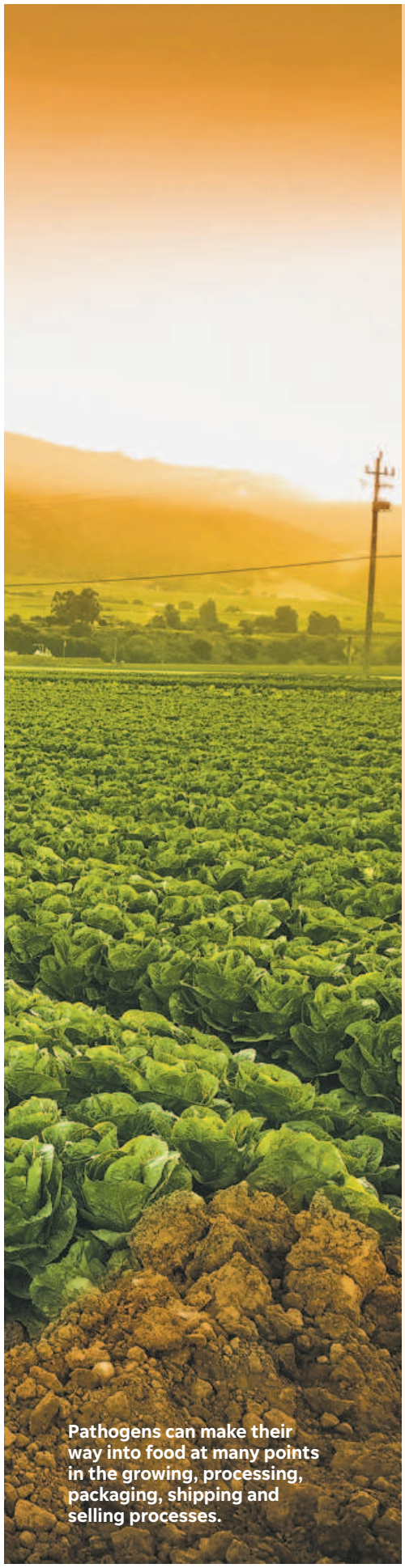

Pathogens can make their way into food at many points in the growing, processing, packaging, shipping and selling processes.

GETTY IMAGES

USDA, groups work together to investigate, prevent catastrophic foodborne illnesses

By Patricia Kime

When the Centers for Disease Control and Prevention (CDC) recommended in November 2018 that everyone — consumers, restaurants, food pantries, grocery stores ... everyone — throw out their romaine lettuce, University of Missouri freshman Stephanie Ingberg promoted the message on local media.

Ingberg knows something about E. coli, the bacteria that CDC officials said sickened 62 people in 16 states during the outbreak. She had nearly died months earlier, having eaten romaine contaminated with the bacteria.

"You never think it's going to happen to you. People really should listen. If I had waited one more day to go to the doctor, I wouldn't be here right now," Ingberg said.

In 2018, the CDC investigated 24 multistate foodborne outbreaks. While it may seem that these incidents are on the rise, experts say what is actually increasing is the ability to detect them. To do so, a host of government agencies rely on old-fashioned detective work, a vast database and cutting-edge technologies — such as whole genome sequencing — to detect potentially deadly pathogens.

How exactly does this contaminant sleuthing occur? How does information from a sickened person such as Ingberg in Missouri get traced to a canal in Arizona? And once an area is determined to be the source, what is the process for cleaning it up and ensuring it doesn't happen again?

It takes hundreds of local, state and federal investigators from the USDA's Food Safety Inspection Service, the Food and Drug Administration (FDA), the CDC and elsewhere to ensure that contaminants are located and eliminated from the food supply.

And it starts with the patient.

A PATHOGEN'S PATH

When a person with suspected food poisoning goes to a doctor or emergency room, a stool sample is taken. If a pathogen is found to be the culprit, a sample is sent to the CDC, which sequences its DNA to determine its exact genetic makeup. That information is then entered into a database called PulseNet, which compares the DNA with others to determine whether anyone else in the country has been sickened by the same strain.

If the particular germ with the same genetic blueprint pops up in another sample from another state, the CDC then launches an epidemiological investigation called a traceback. Coordinating with state and local public health agencies along with the FDA and USDA, investigators fan out to speak to those affected, going to homes and hospitals to conduct interviews.

According to Dr. Laura Gieraltowski, who leads the CDC's food outbreak response team, officials ask more than 300 questions of the patients to find out what they ate, where they ate it, and what their symptoms are, and recent activities, such as whether they've been to a farm or a petting zoo.

It's a difficult task to nudge memories, Gieraltowski noted. "A lot

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GETTY IMAGES; PROVIDED BY STEPHANIE INGBERG

In January, FDA Commissioner Scott Gottlieb said his agency made changes to improve the food recall process, particularly when it comes to informing consumers.

of people have trouble remembering what they ate yesterday, never mind by the time we talk to them, which could be three weeks after they got sick," she said. "But people who become ill sometimes remember better what they ate around the time that they got sick, so that helps."

Ingberg's case was among the early ones in the E. coli outbreak announced in April. She fell ill in March — before the FDA and CDC began suspecting any problems — feeling poorly on a flight to the Dominican Republic for her high school senior spring break trip. By the next day, she was vomiting and experiencing abdominal cramps and bloody diarrhea. Her mom, also on the trip, took her to the hospital, but physicians there didn't suspect E. coli, and she wasn't tested. As her symptoms worsened and her kidneys began to fail, she was airlifted back to the United States, where she stayed in a coma for a week.

During that time, the CDC flagged her case, and investigators spoke to her mother, who quizzed Ingberg's

Stephanie Ingberg

friends about where — and what — she ate when she wasn't at home.

Just two days before leaving for her trip, Ingberg had eaten a Caesar salad at a Saint Louis Bread Company (known as Panera Bread in the rest of the country). By then, contamination was popping up at other Panera locations, giving investigators a lead.

"We examine all the answers, all the data, here at CDC and look for commonalities and the different food types," Gieraltowski said, referring to the data extrapolated from the questionnaires and surveys.

If they find commonalities, they form hypotheses, then work with USDA (in cases of potential meat and poultry contamination) and the FDA, for all other sources, to trace it to a single locale such as grocery stores, restaurants, suppliers, manufacturers, processors and farms.

In the romaine outbreak, the CDC determined that all patients had eaten leafy greens, specifically, romaine lettuce. With so many sickened, on Nov. 20, the CDC and FDA officially warned people not to eat romaine. Then, by examining the supply chain, CDC and FDA officials narrowed the source to lettuce watered by an irrigation reservoir contaminated with E. coli at Adams Bros. Family Farm in Santa Barbara County, Calif.

Even after identifying that the lettuce was sold at five restaurants in four states, from 11 different distributors and nine different growers, FDA officials said they would continue to investigate, concerned that Adams Bros. Family Farm wasn't the only source.

"No single establishment is in common across the investigated supply chains," the FDA reported. "This indicates that although we have identified a positive sample from one farm ... the outbreak may not be explained by a single farm, grower, harvester or distributor."

PROBLEM POINTS

As the FDA noted, pathogens can make their way into food at many points in the growing, processing, packaging, shipping and selling processes. Pre-harvest contamination can occur directly or indirectly by wild animals, fouled water, soil, dirty equipment and unhygienic human handling. Manure and compost are common culprits. The E. coli outbreak that affected Ingberg was traced back to Arizona. Officials believe the E. coli came from irrigation water contaminated

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A USDA shell egg grader checks to ensure machines are properly cleaned before starting the day's operation.

PRESTON KERES/USDA; NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES (2); JENNIFER OOSTHUIZEN/CDC

by a nearby cattle feedlot.

Salmonella, which live naturally in animals' intestines, can sicken humans when exposed, and cause an infection. During the slaughtering process, salmonella can spread through cross-contamination or poor hygiene practices. When a salmonella outbreak occurred in April 2018, 45 patients indicated they had eaten eggs. By crunching the data on where the eggs were eaten and purchased, the FDA traced the potential source of contamination to Rose Acre Farms facility in Hyde County, N.C. The finding led to the recall of 207 million eggs.

Listeria, which can be found in soil, water and some animals, is another bacteria that can cause serious illness. It was responsible for the deadliest foodborne outbreak in the U.S.: In 1985, listeria-contaminated soft cheese sickened 142, killed 28 and caused 20 stillbirths, according to the CDC.

48 MILLION

The number of Americans who get sick from foodborne illnesses each year

SOURCE: CDC

Foodborne illnesses can cause devastating health consequences for those affected and wreak economic havoc. A 2015 Ohio State University study placed the national direct and indirect costs associated with illnesses caused by major outbreaks at $93.2 billion a year.

Farmers stand to lose crops, their revenue and their livelihoods if their facilities are found to be the source of a deadly outbreak. In 2009, the now-defunct Peanut Corporation of America supplied peanuts tainted with salmonella to hundreds of companies, sickening 714 people and contributing to nine deaths. The outbreak, which extended to 46 states, prompted the recall of 2,833 peanut-containing products and led to the finding that conditions at the company's Blakely, Ga., facility were unsanitary. The revelation prompted one of the largest food recalls in U.S. history, causing the company to declare bankruptcy and its top executives to go to prison.

There are steps, however, that farmers and ranchers can take to

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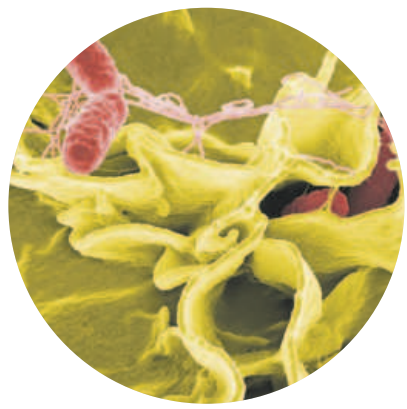
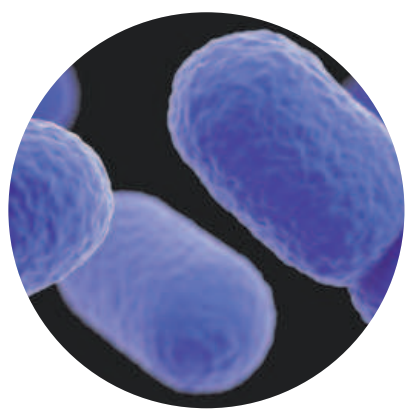
HARMFUL BACTERIA

Foodborne illnesses caused by E. coli, salmonella and listeria have all contributed to widespread outbreaks in the U.S.

Escherichia coli (E. coli)



Salmonella



Listeria

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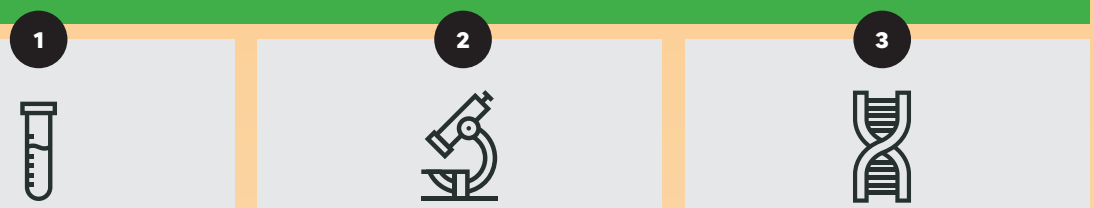
Halting an Outbreak



GOING FORWARD: When illnesses are linked to a contaminated food or food-handling environment, the FDA, its federal, state and local partners and the food industry work to prevent more people from becoming sick. Meanwhile, investigators continue their work to understand exactly where and how the pathogen got into the food supply so steps can be taken to keep the contamination from happening again.

SOURCE: USDA

GETTY IMAGES; PROVIDED BY USDA/FOOD SAFETY AND INSPECTION SERVICE

reduce the risk of contamination. The FDA in October released a 152-page draft, *Standards for the Growing, Harvesting, Packing and Holding of Produce for Human Consumption: Guidance for Industry,* to help farmers comply with the Produce Safety Rule, part of the FDA's efforts to implement the Food Safety Modernization Act (FSMA) signed into law in 2011 by President Barack Obama.

The guidance includes information on health and hygiene, equipment oversight, growing techniques and farm management.

The FDA began inspections under the new rule starting Jan. 26. At the time, Richard De Los Santos, director for produce safety at the Texas Department of Agriculture, said he thought Texas farmers were prepared to comply.

"They're already following (global agricultural) practices, which are almost as stringent as FSMA, so this shouldn't be too big of a change for them. I think the vast majority of these farms are ready for the implementation," De Los Santos said in a release. FDA Commissioner Scott Gottlieb added that his agency made changes to improve the food recall process over the past year, particularly when it comes to informing shoppers.

"More actions to improve our recall policies are planned, including ways to further improve our ability to track and trace products," he said.

Meanwhile in Yuma, Ariz., investigators are still trying to trace the source of the contamination of the romaine that sickened Ingberg and 209 others, resulting in five deaths. While they suspect it is in sediment in a canal, they are trying to figure out how to eliminate it. They plan to draw down the canal, hoping that once it dries out, the sediment can be removed and the canal repaired.

The local irrigation and drainage district also plans to facilitate communications between vegetable growers and ranches to prevent future contamination of the farms and water sources.

In November, growers of leafy greens also started adding the location where the romaine was grown to their labels to rebuild consumer trust. "We're doing what we can," said Mary Coppola, vice president for marketing and communications at the United Fresh Produce Association. "We're happy consumers are going to get romaine back in their diets."

Ingberg still eats romaine lettuce on occasion, but she has become a stickler for safe food preparation. She also recommends paying attention to recalls: "I'm not obsessed, but if one makes the news, I listen."

STAYING IN THE KNOW

Most food recalls are initiated by the companies that sell the product, but in some cases, a government agency will make the call. What is the best way consumers can stay on top of such information? Other than pay attention to the news, where large outbreaks usually are reported, the agencies responsible for food safety run the website *foodsafety.gov*, which offers several tools to check on current recalls. Consumers can also track current recalls and alerts at *foodsafety.gov/recalls/recent/index.html.* They are advised to not open or use the affected product and return it to place of purchase for refund.

The USDA's Foodkeeper app is another tool that provides information on safe food handling, preparation and storage as well as recall information.

Foodkeeper is available at Google Play and the Apple App store.

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Javier Zamora once worked for others but now operates his own business growing fruit, flowers and vegetables.

PROVIDED BY JAVIER ZAMORA

A Colorful FUTURE

Nurturing diversity is as essential in the people as it is the plants

By Mary Helen Berg

JAVIER ZAMORA RISES MOST days at 4:30 a.m. and works well past dusk. The long days can be tough, but when he gazes over his fields in the rolling hills of Monterey County, Calif., he feels blessed. As a child growing up in Michoacán, Mexico, Zamora picked strawberries for someone else. Today he owns 200 acres, grows his own berries, flowers and vegetables, and employs dozens of workers.

Part of his goal as a successful Latino farmer is to recruit and train a diverse crew to ensure the industry's future, he said.

"I think farming and food production need to reflect what America is," said Zamora, 53, owner of JSM Organics.

Industry advocates agree: If the U.S. agriculture industry expects to thrive and innovate to meet future demands, American farmers need to be as diverse as the crops they grow.

"Increasing diversity among farmers and other agriculture professionals will play a key role in driving the innovation, creativity and determination that will be needed to increase feed production, reduce waste and improve infrastructure in order to sustainably feed 9 billion people by 2050," said Jennifer Sirangelo, president and CEO of the National 4-H Council, the agricultural youth development program that has helped create a pipeline of future farmers for more than a century.

U.S. farmers are a homogeneous

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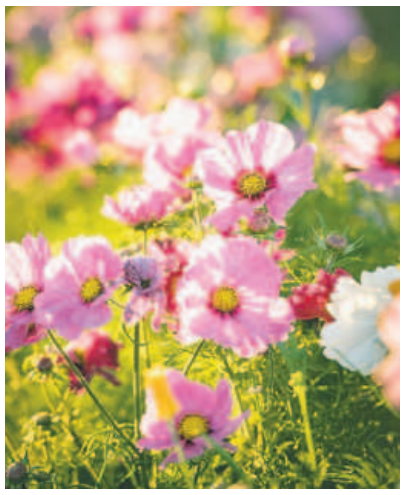


SHAWN LINEHAN PHOTOGRAPHY

Victor Cortez, above, and Juan Gonzales, right, each launched their farms at a farm incubator operated through the Agriculture and Land-Based Training Association in California.

bunch. Of the country's 3.2 million farmers, nearly 96 percent are white, and out of all farmers, 70 percent are male, according to the 2012 Census of Agriculture conducted by USDA's National Agricultural Statistics Service. A little more than two percent are Native American, less than two percent are black or African-American and less than one percent are Asian. And while 43 percent of agricultural field workers are Hispanic, only 3 percent of farmers are, 2012 government statistics show.

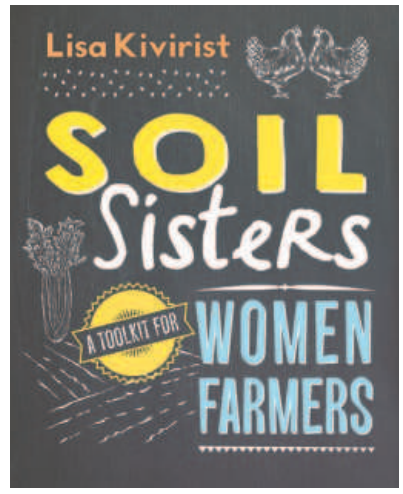
There are signs of progress. For example, the number of minority-operated farms increased 6.9 percent from 2007, and Teresa Romero, a Mexican immigrant, will be United Farm Workers' first female president. But if the industry is to conquer future challenges, "engaging all of our potential talent is essential," Sirangelo said.

REPLACING RETIREES

The average age of a farmer, which has been rising for decades, is 58, according to the 2012 USDA agriculture census. New farmers aren't joining the field fast enough to replace older workers — the number of farmers entering the industry dropped 20 percent between 2007 and 2012. And there's a shortage of available young people who are training to fill openings — only 35,000 graduates were estimated to be available for 58,000 agriculture and environment jobs through 2020, according to the USDA.

"There's just a crisis with the aging farming population," said Patricia Carrillo, executive director for the Agriculture and Land-Based Training Association (ALBA). Funded in part by the USDA, the nonprofit operates a 100-acre organic farm incubator in California's Salinas Valley and provides agricultural education for aspiring farmers on a sliding scale and subsidizes land for socially disadvantaged farmers and people of color.

Up to 90 percent of ALBA students are Latino, said Chris Brown, development director for the group. Many are fieldworkers who dream of farming their own land.



JOHN D. IVANKO PHOTOGRAPHY; PROVIDED BY LISA KIVIRIST

From left, Jen Riemer, Lisa Kivirist, Cara Carper, Peg Sheaffer and Kriss Marion are part of Soil Sisters, a group that connects women farmers. Kivirist started the organization after opening the Inn Serendipity bed-and-breakfast, above, with her husband. The movement also spurred a book.

To fill the boots of those who are retiring, the industry will need to attract more farmers from diverse backgrounds, Carrillo said.

"There are very low entry rates for beginning farmers, so really what (ALBA is) doing is training the new farmers that are going to come in and hopefully take over all of the farmland that is becoming available," she said.

BREAKING THE 'GRASS CEILING'

While the benefits of diversifying crops and operations is a common topic within the agriculture industry, few are talking about the need for more diversity among people, according to Kendall Lamkey, chair of the agronomy department at Iowa State University.

The male-dominated field needs the perspective of more women to build resilience and move the industry forward, Lamkey said, and his department actively recruits female students to introduce them to agronomy.

"I think if we get more women out on the farm, they'll think differently about farming," Lamkey said. "I don't know how they'll think, but they'll think differently than white guys; I'm pretty sure of that. And they'll do different things, and they'll care about different things, and it'll change agriculture."

Lisa Kivirist agrees. She's doing her bit to break the "grass ceiling" as an advocate for female farmers and co-founder of Soil Sisters in southern Wisconsin. Kivirist left Chicago and a "normal job" in advertising for rural life in 1996 and opened the solar-powered bed-and-breakfast Inn Serendipity with her husband. Feeling isolated living in the country, she invited local women to a potluck, a gathering that evolved into a network of 225 female farmers who share resources and host an annual event to showcase women-owned farms.

Women are natural stewards of the land, and their focus is to protect it for future generations, said Kivirist, 51, author of *Soil Sisters: A Toolkit for Women Farmers*.

CONTINUED »

JAMEL MOSELY-MEL/EMEDIA

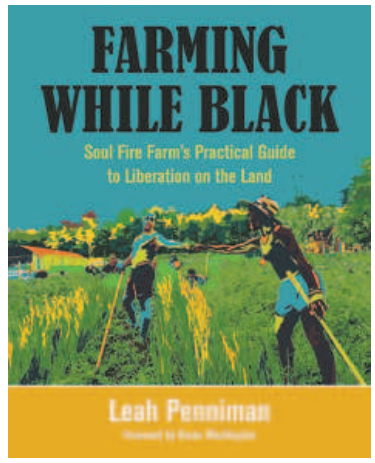
Leah Penniman, author of *Farming While Black: Soul Fire Farm's Practical Guide to Liberation on the Land,* believes those with diverse backgrounds strengthen the food system: "Diversity equals resiliency."

"Women have an intuitive talent for nurturing — be it kids, be it soil, be it plants," Kivirist said. "We also have a shared desire for education, and if you combine those things of caring for our land, of cultivating healthy food and providing a means to share that information, that's powerful. That can transform not only what's on our plate, but I'd argue the health of our country."

Farmers should reflect Mother Nature, she said. "Nature is diverse. Nature doesn't plant just one seed, and we need our farming base to reflect that."

GROWING THE GRASSROOTS

Diverse growers bring wide-ranging experiences and backgrounds that will ultimately strengthen the food system and ensure that fresh, healthy food is widely available to every community, said Leah Penniman, author of *Farming While Black: Soul Fire Farm's Practical Guide to Liberation on the Land.*



PROVIDED BY LEAH PENNIMAN

"By not having the voices of many cultures — immigrant communities, Asian communities, Latinx, black, indigenous communities — we're creating a really narrow sense of what it means to produce food," said Penniman, 38, who is also co-director of Soul Fire Farm. "And that can undermine ultimately our food security because we know by emulating ecosystems that diversity equals resiliency."

Located northeast of Albany, N.Y., Soul Fire Farm provides an immersive program each summer for black, indigenous and other people of color to learn basic farming and healthy food preparation skills. The cost of the session is offered on a sliding-scale, and the waitlist is yearslong, Penniman said.

"There's no scarcity of black and brown farmers who want access to land and want to do this work," Penniman added. "But we're shut out because we don't have access to capital and land because it was taken from our families, and it's not easy to get back. It's part of the healing of a racially charged past for our nation to figure out how to correct those harms."

ACCESS IS KEY

Nonprofits like ALBA, grassroots groups like Soul Fire Farm and Soil Sisters, government programs and national support organizations all provide resources to help farmers like Javier Zamora gain a foothold in the industry.

When Zamora came to the U.S. at age 20, long before the success of JSM Organics, he lived "the whole American Dream" and had a career in the restaurant industry, he said. But during the economic downturn in 2005, Zamora lost his job and his home. Because of his low credit rating, he couldn't rent an apartment for his family.

"We went from the penthouse to the *perros* (dog) house," he said.

Zamora earned a GED and returned to school to study horticulture and organic production. Then he attended ALBA's 10-month training program, where he learned crop planning, marketing and other helpful information. He completed the program in 2012, leased an acre and a half and began to farm.

Zamora acquired more land through a patchwork of assistance that included help from ALBA, California Farm Link — a nonprofit that supports independent farmers with loans and matches them with available land — and a low-cost $300,000 loan from the Farm Services Agency (FSA).

USDA provides a variety of resources to assist historically underserved communities — women, African-Americans, Alaskan Natives, Latinos, Asians and Native Americans. For example, in 2018,

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Marcus Hollan, executive director for the Cultivating Change Foundation, supports LGBTQ agriculturists.

the department dedicated $9.4 million in grants for veterans and socially disadvantaged farmers and ranchers. FSA provides programs for women and minority farmers and ranchers, as well as loans for new farmers through its Direct Farm Ownership loan and the Beginning Farmer and Rancher Development Program.

In addition, national organizations such as Minorities in Agriculture, Natural Resources and Related Sciences, a 34-year-old professional organization, help minority students and professionals network and advance in the agriculture industry. The Cultivating Change Foundation (CCF), a nonprofit founded in 2016, supports members of the LGBTQ agriculture community through advocacy, educational and networking opportunities, including an annual national conference.

These efforts play different roles but share one critical goal: bringing people of diverse backgrounds into the industry.

"As the complexity of societal needs continues to expand, and resources are rapidly being depleted, we have to work smarter in the agriculture industry," said Marcus Hollan, CCF's executive director. "The only way to get there is by not excluding anyone from the table."

EMBRACING DIVERSITY

Leon Etchepare, a fourth-generation farmer in Maxwell, Calif., manages Emerald Farms, his family's 6,000-acre ranch. He oversees 4,000 acres of almond and walnut orchards as well as a large vegetable seed production operation with his husband, Andrew Pentecost, and their two children.

As an only child, Etchepare, 40, is ultimately the sole person who will continue the family's operation. "If I didn't have a feeling of acceptance (as a gay man) to come back into the fold and into agriculture, my dad would have put the family ranch up for sale as he's headed into retirement ... and the family farming aspect of this would have died," Etchepare said. "I'm sure I'm not the only story out there like that."

"There's no scarcity of black and brown farmers who want access to land and want to do this work. But we're shut out because we don't have access to capital and land because it was taken from our families, and it's not easy to get back."

– LEAH PENNIMAN, farmer and author

If crop diversity is critical to maintaining healthy soil on a farm, diversity among people is important for the health and resilience of the industry, said Etchepare.

"We're probably one of the most diverse farming operations that I know of," he said. "We grow hundreds of different species and thousands of different varieties. We have very good success keeping diversity in our crops, which is a very good correlation to diversity regarding people in the industry."

ALFONSO BRESCIANI/WARNER BROS.

The contemporary drama, *Queen Sugar,* chronicles the lives and loves of the oft-battling Bordelon siblings, set on a farm in Louisiana.

MODERN-DAY GRIOT

Queen Sugar, the hit cable series about a family of sugar cane farmers, will premiere its fourth season on the OWN network this summer.

The show follows the triumphs and trials of the fictional Bordelon siblings as they manage their family legacy — 800 acres of Louisiana soil. Based on Natalie Baszile's novel of the same name, *Queen Sugar* was brought to the screen by Ava DuVernay and Oprah Winfrey.

Leah Penniman, author of *Farming While Black: Soul Fire Farm's Practical Guide to Liberation on the Land* and co-director of Soul Fire Farm, said everyone tells her to watch the show, but so far she's seen only one episode. Still, she believes *Queen Sugar* potentially plays an important role, since contemporary media is much like the griot, or storyteller, in some traditional African cultures.

"The stories (media) tell are what shapes our values and our actions," Penniman said. "So, when media chooses to uplift the stories of black agriculturalists that are noble and dignified, that's going to influence the way all Americans see us and see our place in the food system."

— Mary Helen Berg

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TECHNOLOGY & ADVANCEMENTS

Benson Hill employee Kevin Wang prepares a drone to evaluate field trials validating the company's CropOS cloud-based platform, which uses machine learning to predict plant cross-breeding outcomes.

BENSON HILL BIOSYSTEMS

Can Technology Solve World Hunger?

Machine learning is supercharging agriculture production

By Matt Alderton

ONCE UPON A TIME, the only way to produce more food was to farm more fields. When you consider challenges that include climate change, land scarcity and water insecurity, that's no longer a viable solution. Instead of more farms, humanity needs better farms, said Kumar Singa, project manager of the Living Lab at Siemens Corporate Technology in Princeton, N.J. In 2018, his team unveiled a project with a goal of applying automation technology to a growing concern: world hunger.

Singa said that Siemens' contributed modular plant towers that resemble a tiered cake of egg crates and soil. These Autonomous Agricultural Pods, or AgPods, are "micro vertical farming units" outfitted with grow lights and wireless sensors that measure moisture, pH, temperature and other variables. Part of the Internet of Things (IoT) — physical items that aggregate digital information and stream it to the cloud for the purpose of providing intelligence or services — these sensors stream real-time data to MindSphere, Siemens' cloud-based operating system, which continuously assesses plant health and automatically

TECHNOLOGY & ADVANCEMENTS

Benson Hill employees Soumitra Khair and Abree Lamke review corn phenotypes in the company's St. Louis greenhouse.

BENSON HILL BIOSYSTEMS

adjusts crop inputs to provide optimal growing conditions. For example, when plants need water, the system alerts autonomous robots that subsequently transport AgPods to a watering station to receive the precise amount of needed moisture.

The system's linchpin is machine learning: Algorithms inside MindSphere ingest terabytes of crop data, then pair predictions with outcomes to isolate which inputs produce the best outputs with the fewest resources. In other words, computers do what farmers have done for millennia, but faster and more precisely: They observe how crops are growing, make guesses about what's helping or hurting them — too much water, for instance, or not enough — and then make adjustments. Over time, they watch how various tweaks affect crops and commit the lessons to memory, increasingly calibrating growing conditions each time to produce more and better crops, more quickly and with a smaller environmental footprint.

"By combining the IoT with knowledge of the crop, I can maximize my crop yield in the shortest possible time, using the least amount of power and the least amount of water," Singa explained.

Currently, AgPods are still in the testing phase, so not yet commercially available. Siemens is working with Rutgers University through a FutureMakers project to further test the technology. Eventually, Siemens hopes that the AgPods will be beneficial for "any grower ranging from a single farmer with a single AgPod to huge farms with self-managed AgPods."

Because they're compact, Siemens initially is testing AgPods with leafy greens that can be sustainably grown indoors in urban warehouses. With just

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AgPods constantly monitor what plants need.

SIEMENS

a few modifications, however, Singa said AgPods can be scaled up and re-fashioned for outdoor use to accommodate virtually any type of crop in practically any environment. Used on a global scale, Singa hypothesized, such a system could "help solve a huge food crisis."

It's just one example of how machine learning can address world hunger by pairing new capabilities with age-old farming techniques. Here are three others:

BENSON HILL BIOSYSTEMS: ENGINEERING BETTER CROPS

To the naked eye, corn is corn. But crops aren't clones. Like humans, each has distinct characteristics based on its individualized genetic profile. One corn variety, for example, might taste sweeter than another. Another might be more resistant to disease, or more tolerant of drought. Still another might grow bigger, taller, faster.

To grow healthier, tastier and more sustainable crops, plant breeders traditionally have isolated specimens with desirable traits and combined them through natural or artificial reproduction. Because it hinges on trial and error — breeders must guess which traits will pass from parent to progeny, then test their hypothesis over one or more growing seasons — the process takes many years spanning several generations.

St. Louis-based Benson Hill Biosystems has devised a way to speed things up. Called CropOS, its solution is a cloud-based computing platform that uses machine learning to simulate all potential offspring that might result from crossing one plant variety with another. The outcome is a road map that leads breeders to the traits they want in a fraction of the time, according to Benson Hill co-founder and CEO Matt Crisp, who said CropOS already is being used by research and development departments at seed and ingredient companies. He expects those efforts to yield new seeds for use by farmers within the next three to five years. In some cases, maybe sooner.

"CropOS allows us to process huge amounts of data to associate various genomes with their outcomes. The more we can understand about how plants produce something of value, the easier it is to breed them in a manner that supplies that outcome," explained Crisp, who said seeds won't necessarily cost farmers more money on the front end, but could result in more profit by yielding more and better products for which they can charge a premium.

The potential is even greater when breeders use CropOS in tandem with contemporary gene-editing technology, which allows scientists to streamline breeding by inserting, deleting, modifying or replacing the DNA in a plant's genome.

"It might take you seven to 12 years to breed a better product using conventional approaches. Using CropOS, you could breed the same product in half the time," Crisp said. "Using CropOS plus genome editing, you could get the same product in half of that time."

"Data combined with these sorts of machine learning algorithms brings tailored precision to farming at the field and sub-field level in a way that we've never seen before."

– SAM EATHINGTON, chief science officer at The Climate Corporation

The possible effect on the global food supply is evident in crops like soybeans, which over many generations have been bred to increase crop yields at the expense of protein content. The combination of machine learning and gene editing that CropOS utilizes could help farmers grow soybeans that are as nutritious as they are prolific.

"The intersection of machine learning with plant biology will allow us to create faster — and for less cost — crops that are healthier and more sustainable," Crisp said. "And that's really powerful."

THE CLIMATE CORPORATION: MAKING SEEDS SUCCESSFUL

Real estate agents are famous for the "location, location, location" mantra. As it turns out, so are farmers, whose output hinges not only on what crops they plant, but also on where they plant.

"Productivity on a farm is a function of genetics, management practices and the environment. It's quite a complex equation," said Sam Eathington, chief science officer at San Francisco-based The Climate Corporation, a Bayer subsidiary that focuses on agricultural data science.

It's the same equation that Benson Hill is trying to solve. Instead of using genetic data to breed new plant varieties, however, Climate is using it to pair

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The Climate Corporation created FieldView to allow farmers to monitor field maps in real time. Its newest project, Seed Advisor, uses advanced technology to recommend specific crops.

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existing plant varieties with individual fields based on the growing conditions in which they perform best.

"In a farming operation today, you look at what performed well for you last year. And if you're a little more sophisticated, maybe you get some data from local trials or from your seed providers. That's how you select what hybrids to plant on your farm next year," Eathington said. "We have a lot of data from our research programs and from our work with growers. So we looked at that and wondered: Could we take all that data and process it to make insights that help us recommend what hybrid a farmer should plant on their field?"

To perform these tasks, Climate created Seed Advisor, an agricultural matchmaker that uses machine learning algorithms to parse crop data with environmental data from farmers' fields in order to make recommendations about which crop varietals they should plant, where and at what rate. Based on inputs that include climate, soil type and yield, recommendations are tested, and the results used to further train and refine the algorithm such that it improves after each growing cycle.

During trials that began in 2017, Climate compared the varietals it recommended with those preferred by farmers and found that the former outperforms the latter 80 percent of the time, adding an average of nine bushels per acre to farmers' yields on the exact same ground.

"If we can increase yields by being smarter about what seeds to select, I believe we will also be able to increase things like water efficiency using the same method," explained Eathington, who said Seed Advisor is currently undergoing testing and is expected to make a full commercial rollout in 2020. At $4 per acre, Climate expects it to benefit small and large growers alike. "Data combined with these sorts of machine learning algorithms brings tailored precision to farming at the field and sub-field level in a way that we've never seen before."

BLUE RIVER TECHNOLOGY: WEEDING OUT WASTE

In agriculture, weeds are wicked. But then again, so are weed killers. Every year, farmers spend $25 billion to spray 3 billion pounds of herbicides, runoff from which can contaminate water and soil while also giving rise to herbicide-tolerant weeds that threaten long-term agricultural productivity.

To maximize herbicides' benefits and minimize risks, John Deere subsidiary Blue River Technology of Sunnyvale, Calif., has pioneered See & Spray machines that use computer vision and machine learning to apply herbicides with a surgical touch, ensuring that chemicals reach only targeted areas in small quantities in order to reduce waste and environmental fallout.

"Productivity on a farm is a function of genetics, management practices and the environment. It's quite a complex equation."

– SAM EATHINGTON, chief science officer at The Climate Corporation

Blue River's See & Spray smart machines reduce herbicide usage by 80 percent.

BLUE RIVER TECHNOLOGY

Here's how it works: Affixed to tractors that comb farmers' fields, the machines use cameras to identify plants, images of which are fed to computer processors that use machine learning algorithms to instantly classify them as weeds or crops. As if spot treating stains on a carpet, the machines apply herbicides only to the former. Finally, a second set of cameras checks the machines' work, conclusions from which are used to further train and refine the algorithms, resulting in a closed-loop system that gets perpetually better over time.

According to Blue River, the system reduces herbicide usage by 80 percent. Company co-founder and CEO Jorge Heraud said sprayers are currently in the "advanced prototyping stage," and he eventually sees his machines applying in the same precise manner — plant by plant instead of field by field — fertilizers, fungicides, insecticides and water.

"This has three big benefits," Heraud said. "No. 1 is sustainability — precisely spraying herbicides only where they're needed prevents herbicide-resistant weeds and reduces waste. Another benefit is profitability. One farmer told me he spends $250,000 a year to control weeds; imagine if he could cut that to $50,000 per year. And the third benefit is increased understanding; because our machines go through the same fields multiple times, you can use them to track plants from seed to harvest and see how they grow. Scaled across multiple fields, that can help us crack the code of how to farm better."

Ultimately, that's the promise of machine learning: Whether it's used to breed, seed or weed crops, it accelerates agricultural evolution.

Singa concluded: "Imagine a farmer who's been farming for 35 years. In that time, he will have seen 70 to 80 cycles of crops on his farm, learning along the way what issues his farm faces and how to mitigate them. As a result, his 80th crop is bound to be much better than his first crop. With machine learning, we can generate the same kind of knowledge faster and more efficiently."

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Precision farming does not only mean autonomy and automation, it also encompasses connected agronomic services which help farmers make business-critical decisions based on real time data. With CNH Industrial equipment, the farmer retains ownership of their data and can select which external partners they share it with for further agronomic support.

Moreover, CNH Industrial believes farmers should be able to choose the applications and systems which best meet their needs. This has led to the creation of an 'open architecture' philosophy, which has seen the Company enter into strategic partnerships with industry leading agribusiness providers enabling customers to seamlessly share in-depth, real-time machine information with AgDNA, The Climate Corporation, FieldView, and Farmers Edge digital management systems.

This focus on precision farming technologies reflects CNH Industrial's long-standing commitment to sustainability. With the global population set to top nine billion by 2050, we know the world's farmers will need to produce more food than ever before, and the only way to achieve this is to provide them with the most advanced tools to increase yields and optimise inputs sustainably, securing long term farm prosperity.

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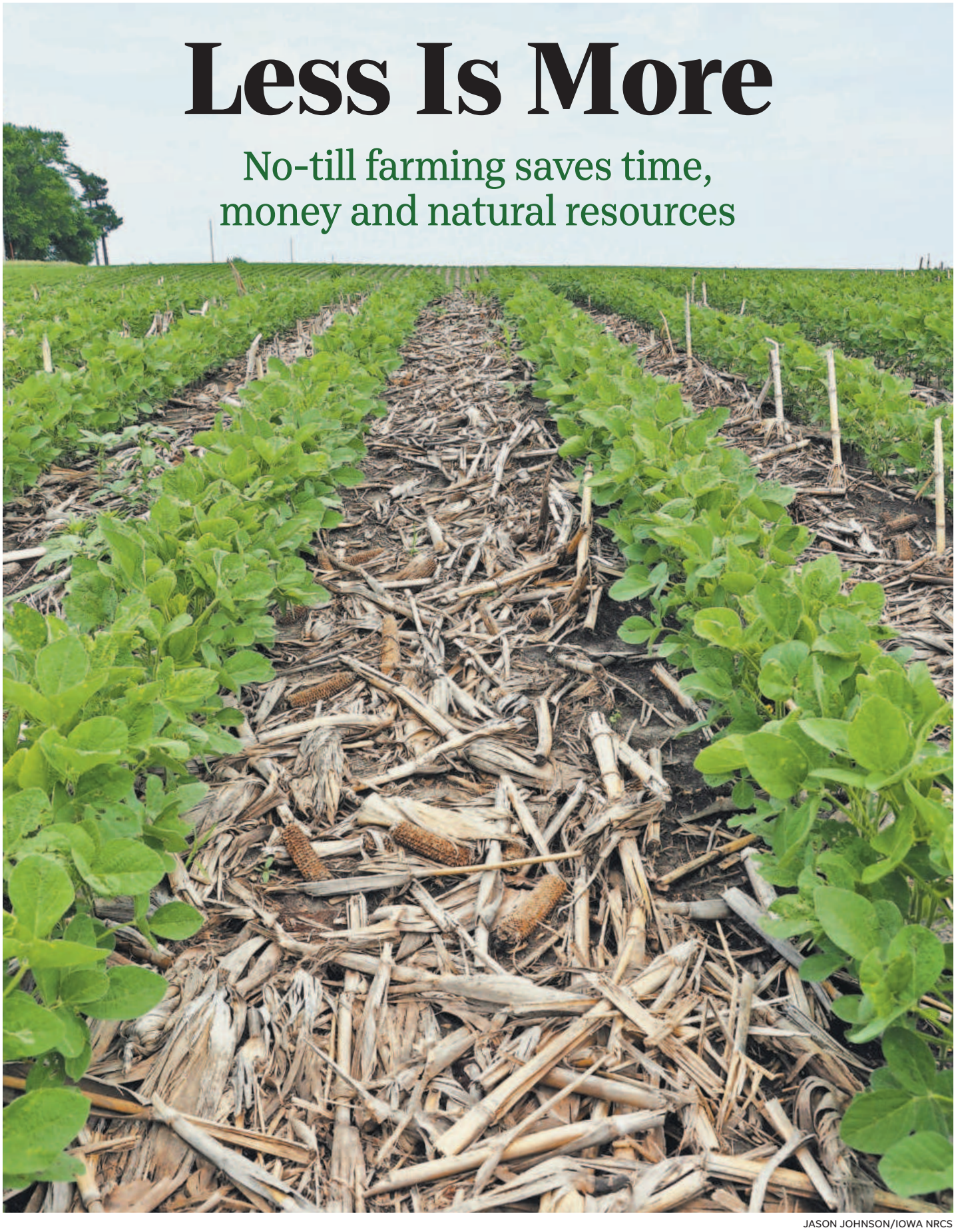

JASON JOHNSON/IOWA NRCS

On a Union County farm in southern Iowa, no-till planted soybeans grow among the previous year's corn residue.

By Brian Barth

HISTORICALLY, FARMERS HAVE TILLED their land multiple times a year to prepare for new plantings. Turning the soil affects crop residue — eliminating it following harvest and preserving it between plantings, which keeps roots in place and holds the soil from below. It aerates the ground and creates a layer of stubbly mulch on top to protect the earth from pounding rains. The mulch helps to prevent weed growth and enriches the soil with organic matter as it decomposes.

Tillage has long been synonymous with farming, so many might be surprised to learn that there's a popular trend toward avoiding the agricultural practice today.

"No-till allows you to skip a lot of steps compared to conventional tillage systems."

– JOSH ANDEREGG, Iowa farmer

According to the USDA, continuous no-till has been adopted on 1 in 5 cultivated acres in the U.S., and the agency is offering numerous forms of assistance, both technical and financial, to increase that number. Why? Simply put, churning the soil also destroys its natural structure, reducing its water- and nutrient-holding capacity. And now when it rains, loose, powdery sediment results, causing pollution in nearby streams rather than supporting plant growth.

Josh Anderegg, who farms several hundred acres in Clayton County, Iowa, points to another benefit: cost savings. "No-till allows you to skip a lot of steps compared to conventional tillage systems," he said. "You're not making pass after pass on the tractor over each field, which cuts costs dramatically." Anderegg, 30, who has been farming on his own for a few years, estimated that he saves approximately 50 percent on labor, fuel and equipment costs by not tilling. He receives support to implement no-till practices through two USDA programs: the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program. The former offers financial assistance to recoup a portion of the upfront costs associated with implementing no-till practices, while

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The Rodale Institute, a nonprofit that promotes organic practices, invented a roller crimper, which crushes crops on top of the soil, creating a weed-restricting mulch barrier.

the latter provides a per-acre payment.

USDA research seems to support Anderegg's anecdotal evidence of cost reductions. One 2017 study found that fuel use was reduced on average from more than 6 gallons of diesel per acre annually to less than 2 gallons, a 70 percent savings. The agency estimates that for each thousand-acre field, nearly 70 hours of labor is eliminated for each time that field is not tilled — a significant savings, given that farmers often till the same field multiple times each year. Wear and tear on tractors is reduced, as is the need for plow blades, rippers, discs and other tools.

Where farmers run into trouble with no-till is attempting to grow the same crop year after year, especially corn.

Some scientists even see no-till agriculture as a means to reverse global warming. That's because each time the earth is turned, a bit of carbon dioxide is released into the atmosphere. Conversely, when soil is left in its natural state, it pulls carbon from the atmosphere and stores it in organic molecules that are highly beneficial to plants.

With all those benefits, it's difficult to imagine why any farmer would choose to till, ever. But good things never come that easy. One can't simply abandon tillage overnight and expect to achieve the same yields, said Neil Sass, a USDA

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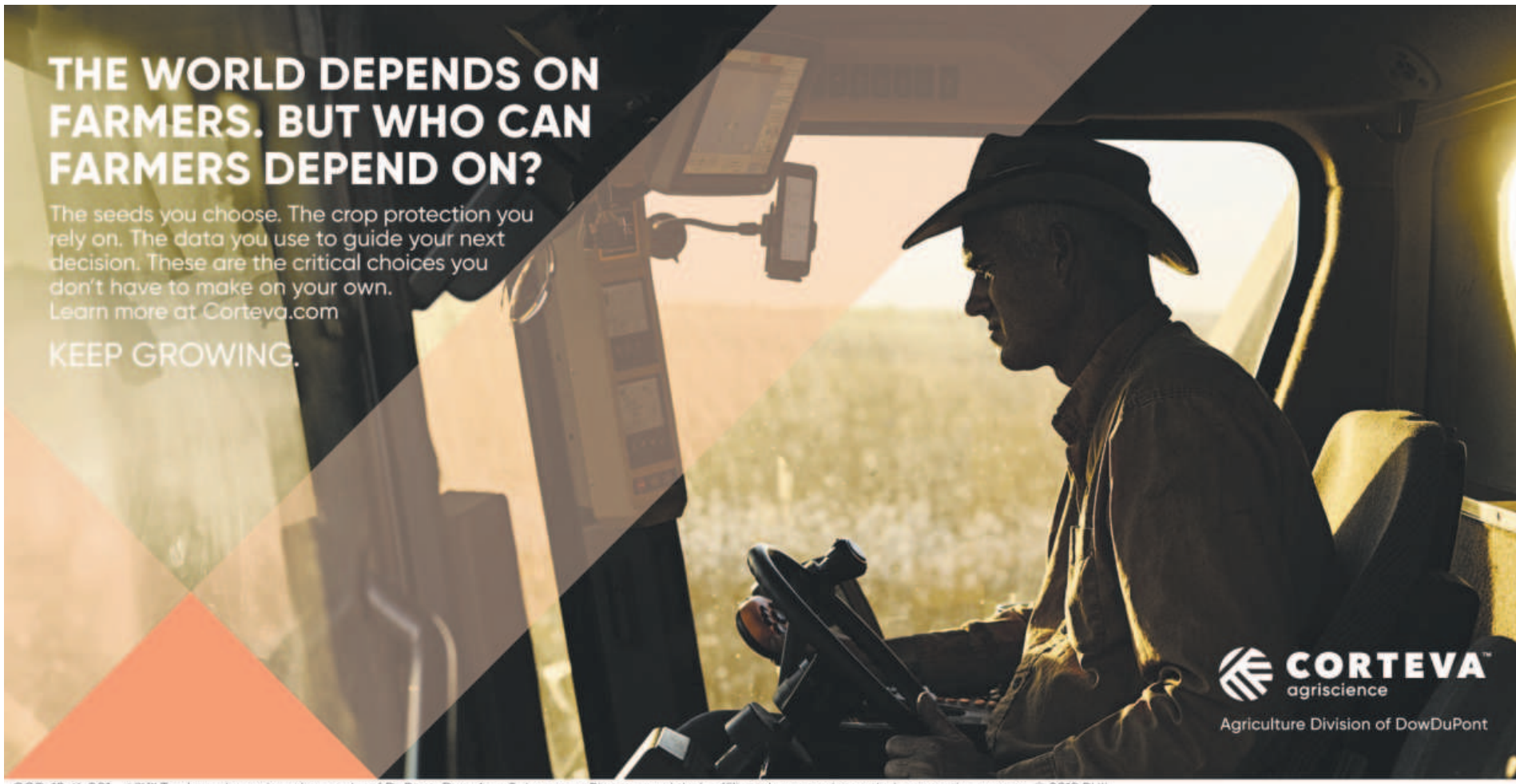

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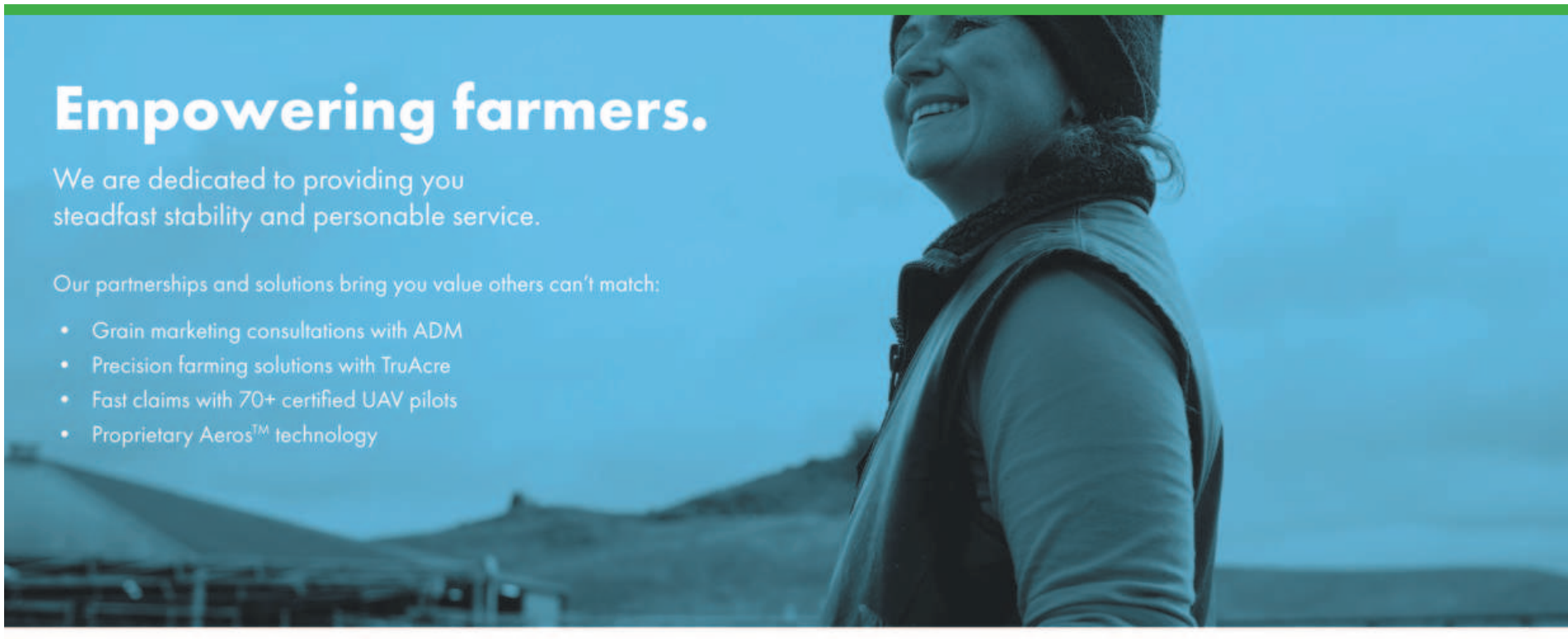

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JASON JOHNSON/IOWA NRCS

A farmer in Mahaska County, Iowa, shows off signs of healthy organic matter in his soil after several years of not tilling.

soil scientist at the Natural Resources Conservation Service office in Iowa. There are new cultivation techniques to learn and equipment to be modified. But most of all, he said, patience is required. After tillage has ceased, earthworms and other soil organisms will naturally begin to redevelop what soil scientists call "tilth" — the moist, crumbly structure that plants thrive in.

"Soil health improves over time if you treat it right," Sass said. "You can't just quit tilling and put your seeds in the ground. You need to have a plan."

One of the easiest ways to transition to no-till is with an alfalfa hay crop, Sass noted. This perennial legume can be harvested for several years without tillage or replanting, while its roots work to improve the soil. He recommended following that with soybeans and then maintaining a rotation of soybeans, corn, hay crops and small grains, as each species has a different give-and-take relationship with the soil. Where farmers run into trouble with no-till is attempting to grow the same crop year after year, especially corn, he said. Planting a fall cover crop — species that are not intended for food, but to add nutrients and organic matter to the soil, while holding it in place through the winter months — is a tremendous boon to no-till systems.

The counterintuitive idea that farmers could dispense with the practice gained steam following the Dust Bowl in the 1930s. This was a time when mechanization had enabled faster, deeper and more frequent tillage on a vast scale. Then, in a yearslong period of drought, Americans learned what can happen when loose, lifeless soil is left exposed to

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USDA

NO-TILL GOES VIRAL

To encourage more farmers to reduce tillage, Neil Sass, a USDA soil scientist at the Natural Resources Conservation Service office in West Union, Iowa, launched a "No-Till November" social media campaign. It aims to spark a cultural shift away from the pristine image of clean and bare fields to highlight the value of a rugged, natural look. Hashtags like #donotdisturb and #keepthestubble, encouraged farmers to post photos of their untilled fields — and were a nod to another November cultural phenomenon: the Movember movement, in which men are encouraged to grow mustaches and fundraise to raise awareness for health issues like prostate cancer prevention.

"The idea of no-shave November is to highlight men's health," Sass said. "Well, we talk a lot about soil health in November, because that's a time when a lot of tillage typically occurs. So I thought it would be a fun way to spread the message."

— Brian Barth

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JASON JOHNSON/IOWA NRCS

Years of no-till and cover crops are keeping the Muchakinock Creek in Mahaska County, Iowa, cleaner through reduced soil erosion and nitrate runoff.

the elements: Not only does it wash away in the rain, it blows away in the wind. The federal government invested heavily in soil conservation following the Dust Bowl, but it would be quite some time before the no-till idea caught on.

The movement arguably began in 1943 with the publication of *Plowman's Folly*, by agronomist Edward Faulkner. "The fact is that no one has ever advanced a scientific reason for plowing," wrote Faulkner; still, his ideas were considered somewhat outlandish at the time. Sass said that improvements in planting machinery in the '60s and '70s made no-till more feasible. A device called a "row cleaner," which smooths the soil and clears debris from the previous crop as each seed is deposited, is the key piece of equipment, he said, allowing farmers to prepare the soil and plant with a single pass on the tractor.

But it was another technological advancement in the '90s — genetic engineering — that encouraged more farmers to give no-till a try. Besides loosening the soil, tillage has long been relied on to kill weeds. Even after a crop is planted, farmers often make a pass through their fields with light equipment that scraped out sprouting weeds as they emerged between the rows of seedlings. The advent of herbicide-tolerant crops, said Sass, allowed farmers to pass through and quickly spray any weeds as they emerged, even as the crop matured, eliminating tillage from the growing cycle entirely. "Genetically modified crops have made things much easier," said Sass. "Since those came out in the late '90s, tractor implements have become even better refined for no-till."

70

THE NUMBER OF HOURS A FARMER SAVES FOR EACH 1,000-ACRE FIELD NOT TILLED

In other words, there are fewer excuses to not try no-till. Farmers typically see a slight reduction in yields for the first few years, but over time many find that untilled fields outperform those that have been plowed.

There are variables to consider, however. No-till yields tend to be best in warmer regions with well-drained soil. In colder areas with heavy, wet soil, it is less effective. The approach works well with grains and legumes, but is less practical for vegetable crops. Organic systems have a reputation for being more difficult to convert to no-till — the herbicide-tolerant varieties that make things easy in conventional systems are not permitted under organic regulations — but some farmers have found ways to make it work. They employ a special tractor implement called a roller crimper, which knocks down crop residue and crushes it on top of the soil to create a weed-restricting mulch barrier between crops.

Anderegg recommended easing into it. He uses the technique part of the time, which is not uncommon. Only 1 in 5 acres nationally are entirely without tillage, while reduced tillage techniques are employed on more than half of some crops, including corn and soybeans. In his experience, younger farmers are more apt to give it a try, indicating that no-till will only become more common.

"When a farmer has done things a certain way for the past 40 years, it's really hard to encourage them to change," Anderegg said. He certainly has no plans to go back. "We're getting a lot of heavier rains lately, which means more erosion. Last summer we had 14 inches of rain in one day. My no-till fields held the soil."


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Preserving Pollinators

High-tech approach to monitoring bees may provide key to saving them

TECHNOLOGY & ADVANCEMENTS

Pesticides have been shown to alter a bee's ability to forage, among other important tasks.

LANCE CHEUNG/USDA

By Caren Chesler

IF YOU LIKE TO eat, you should worry about bumblebees — they're the most important insect pollinators of crops such as cranberries, blueberries and tomatoes, according to Clay Bolt, a communications officer with the World Wildlife Fund.

According to the United Nation's Food and Agriculture Organization, 90 percent of the world's food supply comes from about 100 crop species, and 71 of those crops (especially fruits and vegetables) rely on both "domesticated" honeybees and "wild" bumblebees.

While honeybees are the species most often imported to field crops for pollination, bumblebees are considered the most important native pollinators in North America. "If all bumblebees disappeared, it is highly likely that we would feel the ripples of their loss, in terms of the foods we eat, the loss of economic benefits and the general integrity of the natural world," said Bolt.

Which is why researchers have been working to prevent the loss of these integral pollinators. Pesticide use is one factor that has been linked to the decline of bee populations, and a November 2018 study, led by Harvard University and published in *Science* magazine, further supports the theory that these chemicals may be what's killing bumblebees. Researchers have been gathering data for years about how pesticides alter a bee's ability to forage for food, but few have shown how these chemicals modified the bee's behavior back in its own hive — a critical piece of the puzzle.

"For the past couple of decades, we've gotten a lot better at understanding what's going on outside of the nest, what foragers are doing outside, but there's still this whole incredibly complicated and largely unknown world of what's going on inside of the actual bee colonies," said Harvard University biologist James Crall, the study's lead author. "So we've been developing tools that let us open up that black box and understand a little more of what's going on."

The study looked at imidacloprid — a neurotoxin that belongs to the neonicotinoid group of pesticides — the most widely used insecticide in the world. These pesticides work by disrupting the nervous system of adult bees. Plants absorb the insecticide from the soil or leaves, and it spreads throughout the stems, fruit and flowers. Bees ingest the insecticide when they chew or suck on the treated plants. Even at levels that won't kill the bee, they're adversely modifying its behavior, Crall said.

"I think we need to be looking for ways to reduce or eliminate pesticide use in our agricultural system."

– JAMES CRALL, Harvard University biologist

"We were seeing lots and lots more, first anecdotal, and then really good quantitative evidence, that even those low levels of exposure were disrupting the performance of colonies in the long term," Crall said. "The challenge is that it's easier to quantify when bees are dead. It's a little harder to quantify how pesticides might alter subtle aspects of behavior, and what this means for the growth and health of the colony."

SCIENTIFIC LEAPS

In the past, researchers simply looked inside the hive, with a naked eye or video, and watched how bees acted. While bumblebee colonies can be 50 to 500 — compared with honeybee colonies, which have tens of thousands — the old methods limited the number of bees that could be observed. Instead, Crall and his co-authors tagged individual bees with a tiny QR code to track them in several hives at once.

"We make the code really, really simple so we can shrink it down

CONTINUED »

IMAGES BY JAMES CRALL

Scientists placed bumblebee colonies outside to test the effects of neonicotinoids on nest thermoregulation.

CREATE A BUZZ

People can help boost bee populations by growing a garden or adding native flowering trees or shrubs to yards and minimizing pesticide use, the U.S. Fish and Wildlife Service said.

Leaving some areas of the yard unmowed in summer and unraked in fall can also help because bumblebees need a safe place to build their nests to survive winter. Additionally, try leaving some standing plant stems in gardens and flower beds in winter, the agency suggested.

Bumblebees typically build insulating wax canopies for warmth, but scientists found that the bee colonies exposed to neonicotinoids did not.

QR codes glued to bumblebees' backs helped scientists track their movements.

to a size that can actually fit on the back of a bee and be tracked by a camera," Crall said.

Researchers worked with a dozen colonies, some of which were fed imidacloprid at levels to mimic what they might be exposed to outside. The rest were not fed any pesticide so they could serve as a control group. Two high-resolution infrared cameras on a robotic arm moved over the hives about 12 times a day, stopping at each hive for about five minutes to photograph the activity inside. The pixel code combinations on their backs enabled scientists to collect data on specific bees, such as the direction in which they're standing, how fast they're moving and where in the hive they're located. From that, they could detect changes in the behavior of individual bees over time.

"You can tell if the bee is doing a nursing behavior, or constructing new (wax pots to incubate larvae or store honey and pollen) or foraging," said Benjamin de Bivort, a professor of evolutionary biology at Harvard who worked with Crall. "It was an advancement in bee study in general for (Crall) to connect what you can catch on a camera with particular bee activities."

Bees ingest the insecticide when they chew or suck on treated plants. Even at levels that won't kill the bee, it's adversely modifying its behavior.

What they found was that the bees who ingested the pesticide were less active and spent more time resting and on the outer perimeter of the nest, away from the larvae that needed care. They also interacted less with each other. The result was they were not as effective at keeping the larvae warm. Bees try to maintain an optimal temperature for the developing young, by shivering their muscles to generate heat or fanning to cool it down. Pesticide exposure disrupted these functions.

Bumblebees also typically build a wax canopy or blanket over the larvae to insulate them from the cold. In the control group, nearly all of the colonies built a canopy of some sort. None of the colonies exposed to the insecticide built that protective layer.

Researchers were surprised to find that for bees exposed to imidacloprid, the outcomes were much more pronounced at night. Bees were less active, spent less time nursing the developing larvae within the nest and also interacted with their nestmates less compared to during the day.

The study confirmed something that had been suspected from other lines of evidence: That these pesticides can have quite profound, sublethal effects, which are particularly harmful if you're a social insect like a bee, said Dave Goulson, a biology professor at the University of Sussex in the U.K. who studies bees.

The success of social insects like bees, ants, wasps and termites, is their ability to work as a team. But it relies on them being in the right place at the right time to perform a variety of functions, including looking after and feeding the brood, defending the nest, navigating to find patches of flowers and taking food back to the hive. Interrupting those functions can have profound influence on the colony.

"They do lots and lots of things that require them to be quite intelligent, and bees have pretty big brains for insects. They're able to learn all sorts of quite clever, complicated things," Goulson said. "So perhaps we shouldn't be surprised that a neurotoxic pesticide — something that attacks the brain of the insect — is going to have all sorts of complex and unpredictable effects on bees."

A HISTORY OF EXPOSURE

The 2018 *Science* study wasn't the first to discover how this chemical influences bees. A study published in the journal in 2012 concluded that pesticide exposure changed a honeybee's ability to forage and find its way back to its nest. It was the first clear evidence that pesticides can have a sublethal outcome on bees, meaning it may not kill them, but it can

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A USDA biologist harvests honey from the People's Garden Apiary on the roof of the USDA headquarters in Washington, D.C. Scientists have been studying colony collapse disorder, which mostly affects honeybees.

LANCE CHEUNG/USDA

drastically alter their ability to perform essential functions, like finding food. The Harvard-led study proved that the chemicals' effects go well beyond navigation.

"What we showed in our paper was that (the pesticide) is not just having these specific effects on a limited number of behaviors. The drugs are affecting basically every behavior that we can measure in the colony. That includes the degree of social interaction and their speed," de Bivort said.

Scientists have been trying to identify what's been ailing the bees since the winter of 2006-2007, when keepers began reporting hive losses of 30 percent to as high as 90 percent. Researchers began to refer to it as colony collapse disorder, a phenomenon that occurs when the majority of worker bees in a colony disappear and leave behind food and a few nurse bees to care for the remaining immature bees and the queen. But that term only applies to honeybees, which comprise just one of the 20,000 bee species that exist.

It's a bit of tunnel vision, according to experts, because in fact, other species are influenced by some of the same adverse factors, and because their hives are a lot smaller, the damage may be far worse, Crall said. Honeybee colonies number in the thousands, obscuring the problems of a small number of bees. Bumblebees have smaller populations, making behavioral changes potentially lethal to the colony, Crall said, and that is why he focused on bumblebees.

4,000

THE NUMBER OF KNOWN SPECIES OF NATIVE NORTH AMERICAN BEES

"There's some evidence for effects of pesticide exposure in honeybees for sure, but it seems like the most important effects might actually be on the 19,999 other species of bees (in the world), which are also critically important to how we produce food," Crall said.

While the USDA tests every new pesticide, scientists say those tests are incomplete. The standard test involves exposing a honeybee to a pesticide, leaving it in a little plastic pot for 24 hours or 48 hours, and then looking to see whether it is dead or not — which is pretty crude, Goulson noted. It also doesn't take into account that even if the bee survived, its vital functions may be greatly impaired.

As researchers continue to explore what's causing hive losses, the number of cases of colony collapse disorder reported to the Environmental Protection Agency (EPA) have actually declined. Where nearly 29 percent of hives made it through the winter in 2006-2007, that number dropped to about 23 percent for 2014-2015, according to the EPA. And while winter losses remain somewhat high, those attributed to colony collapse disorder went from 60 percent in 2008 to about 31 percent in 2013, EPA officials said.

"At the same time, every year, there's more and more evidence for just how strongly both natural ecosystems and global crop yields depend on pollinators," Crall said, noting that even if pesticides reduce crop pests in the short term, there may be long-term costs in terms of yields. "I think we need to be looking for ways to reduce or eliminate pesticide use in our agricultural system."

— Doyle Rice contributed to this story.

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USDA

Water Warriors

Experts work to ensure adequate supplies for future generations

By Adam Stone

NO WATER, NO FARMS. It's pretty simple.

Most of the world's stored water goes to farmers — 70 percent of all water usage globally, according to the World Bank — and there isn't enough to go around. At current rates, the world will face a 40 percent water deficit by 2030, United Nations' experts predict.

Standing on the front lines of the issue are the water warriors — men and women who work at the intersection of agriculture and water use. They may be hydrologists or engineers, political activists or community organizers. They help ensure farmers and producers will have the water needed to grow our food, and that the water will be safe, clean and above all, readily available.

IMPROVING IRRIGATION SYSTEMS

As a member of the Yakama Nation in Washington state, Graysen Squeochs, understands that his tribe's strength depends on water availability.

Nestled along a narrow strip that runs for 175 miles on both sides of the Yakima River, the 464,000 acres of irrigable land receive just 14 inches of rainfall on aver-

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USDA's Rural Utilities Service provides much-needed funding to rural communities to rebuild and modernize the nation's water and wastewater infrastructure. USDA funding also supports training and technical assistance, such as NRWA's Circuit Rider program, to ensure clean, affordable drinking water and effective waste management for Rural America.

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Graysen Squeochs works for the Bureau of Indian Affairs Wapato Irrigation Project to help ensure adequate water supplies are available for future generations.

PROVIDED BY GRAYSEN SQUEOCHS

age a year, noted Squeochs, 36. "Without irrigation, it would all just be sagebrush."

To help ensure the success of the land, and the tribe, Squeochs studied hydrology, the science of water management. Today he practices his craft as an engineer apprentice in the Yakama Nation Department of Natural Resources Engineering Program, where he supports a long-running government irrigation initiative.

The region is laced with canals, pipes, valves — all the components of an irrigation system, but much of it is in need of repair. "The system was built with early 20th-century technology, and there has been some 50 years of deferred maintenance. The concrete ages; the steel rusts. The infrastructure begins to fall apart," he said. "Much of it is now being upgraded through cooperative work with the state and various federal agencies."

Squeochs was able to join the Bureau of Indian Affairs Wapato Irrigation Project in part because of his academic achievements, which include a bachelor's degree in environmental science from Washington State University and a master's in water resources science from Oregon State University.

The Wapato project also gives strong preference to Native Americans, a marginalized group that accounts for less than 0.3 percent of graduate and post-doctorates in science and engineering. Only a fraction of those focus on hydrology, making Squeochs a rare commodity.

He carries a heavy load, ensuring adequate water supplies not just for today but for future generations.

"With climate change, we are concerned about the decreased level of snowpack. Precipitation will come in the form of rainfall and not as snow, which means it will go through the surface waterways much faster. We will have to change the storage retention schedules to capture a larger portion of that," he explained.

That also means those creaky old irrigation systems must be made, literally, water-tight.

"The biggest challenge is in making sure we are not losing a lot of water in conveyance," he said. "It means not having leaky canals, making sure every drop of water we draw out of the river is used for a beneficial purpose."

UNDERSTANDING THE LANDSCAPE

Growing up in Lancaster, Pa., it can be easy to overlook the beauty and the fragility of farmland. Jenna Mitchell had to go away to school in Washington, D.C., to fully appreciate it.

"It was a rude awakening for me, to find myself in this very urban environment," she said.

That taste of city life ignited her passion for the environment. She transferred to Penn State and earned a bachelor's in environmental resource management. Today Mitchell, 26, serves as Pennsylvania state director for the Alliance for the Chesapeake Bay, a nonprofit that works to restore and protect the lands and waterways of the Chesapeake Bay watershed.

While the Bay may seem geographi-

CONTINUED »

GET YOUR FEET WET: WATER JOBS IN AGRICULTURE

Environmental engineers

- **2017 median salary:** $86,800 per year
- **Education required:** Bachelor's degree
- **Duties:** Environmental engineers use their scientific skills to solve environmental problems including water management and water pollution.

Conservation scientists and foresters

- **2017 median salary:** $60,970 per year
- **Education required:** Bachelor's degree
- **Duties:** Soil and water conservationists develop programs to make the most productive use of land. They help landowners deal with issues such as erosion, water quality and water conservation.

Hydrologists

- **2017 median salary:** $79,990 per year
- **Education required:** Bachelor's degree
- **Duties:** Hydrologists study how rain, snow and other forms of precipitation affect river flows or groundwater levels. They use their expertise to solve problems concerning water quality and availability.

SOURCE: Bureau of Labor Statistics

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Jenna Mitchell works to keep agricultural runoff from polluting the Chesapeake Bay.

PROVIDED BY JENNA MITCHELL

cally remote from Lancaster, Mitchell said many of its pollutants start as agricultural runoff in Pennsylvania. But it isn't her mission simply to tell farmers to clean up their acts. "We are trying to find cooperative solutions," she said.

With an annual budget of around $5 million, the Alliance receives funding from a range of partners, including the National Fish and Wildlife Foundation, the Environmental Protection Agency, state agencies and private foundations. Much of that is spent to help farmers improve their water situation.

"They may have a barnyard that is just earth and mud, and the animals hang around on that, building up manure all day, which goes into the water supply. We will put in a concrete barnyard so that manure can be scraped into a storage facility," Mitchell said. "We help them install those storage facilities if they don't have them."

The Alliance also helps farmers fortify land adjacent to streams, in an effort to prevent excess fertilizer and other agricultural runoff from entering the water flow. "We are very passionate about buffers — planting trees next to the streams. With trees on a stream bank, they reinforce the banks, and they filter out anything nasty coming down in the runoff," Mitchell said.

Done right, the plantings can become a revenue source for the farmers, yielding fruit, nuts and wildflowers that can be sold at market. "It's a way for them to make a living off every inch of land," she said.

Looking ahead, Mitchell envisions continuing to build a career for herself that embraces these kinds of cooperative efforts, and protecting the water supply while driving mutual benefit. "I am passionate about finding new creative ways to do this, to find who is being left out of the picture and developing new programs that will get them engaged," she said.

FIGHTING FOR FARMER RIGHTS

Bill Diedrich, 64, farms 1,400 acres of almonds, walnuts and pistachios in the San Joaquin Valley of California. Everything he has in this world depends on water.

"Every asset I have is tied up in farm real estate. I'm not diversified. My investment is my farm dirt, and the value of that dirt is directly tied to its water supply," he said. "And in California the right to have water in that dirt is very variable."

To help ensure farmers' rights to water, Diedrich serves as board president of the California Farm Water Coalition (CFWC). "Our main task is to inform the public about the benefits of having vibrant agricultural production in California. We need smart policies, and for that we have to have public backing," he said.

The state has experienced droughts, some severe, in recent years, and supply struggles to meet the demands of an ever-expanding population. Climate change creates added pressures: Snow pack has formed a natural reservoir in the past, but precipitation increasingly comes down as rain, rather than snow, and that's more difficult to manage.

As a result of all these factors, it's tough for farmers to predict how much water will be available from one year to the next. "The biggest issue is supply reliability. We need to know the number so we can plan what we are going to farm and how we are going to farm," Diedrich said.

The biggest sticking points are environmental regulations, such as The Central Valley Project Improvement Act, which diverts some 260 billion gallons of water for environmental causes, and The San Joaquin River Settlement, which sets aside water resources for salmon runs.

Diedrich said he is seeking common ground between farmers and environmental groups. CFWC, for example, partners with the Grassland Bypass Project, an effort to protect sensitive wetland areas by redirecting and recycling water with high levels of naturally occurring minerals.

"We need to find a collaborative solution so that we can solve the environmental problems and still have a reliable water supply," he said. "We want the farm community to get involved with projects to help the fish because until we take care of the fish, we aren't going to be able to take care of the farmers."

USDA WATER JOBS

At the intersection of water and agriculture, there are a range of career opportunities available across USDA's diverse portfolio. Some examples include:

- **Hydrologists** at the Agricultural Research Service use sophisticated techniques to track soil and water conservation efforts on the Columbia Plateau.
- **Water technicians** in the USDA Farm Service Agency's Source Water Protection Program help prevent pollution in the surface and groundwater that serves as the primary source of drinking water for rural residents.
- **Water management experts** at the Forest Service play an important part in managing the areas in the national forests where more than 70 percent of the surface water supply in the western United States originates.

California farmer Bill Diedrich is dedicated to educating others about the importance of water conservation.

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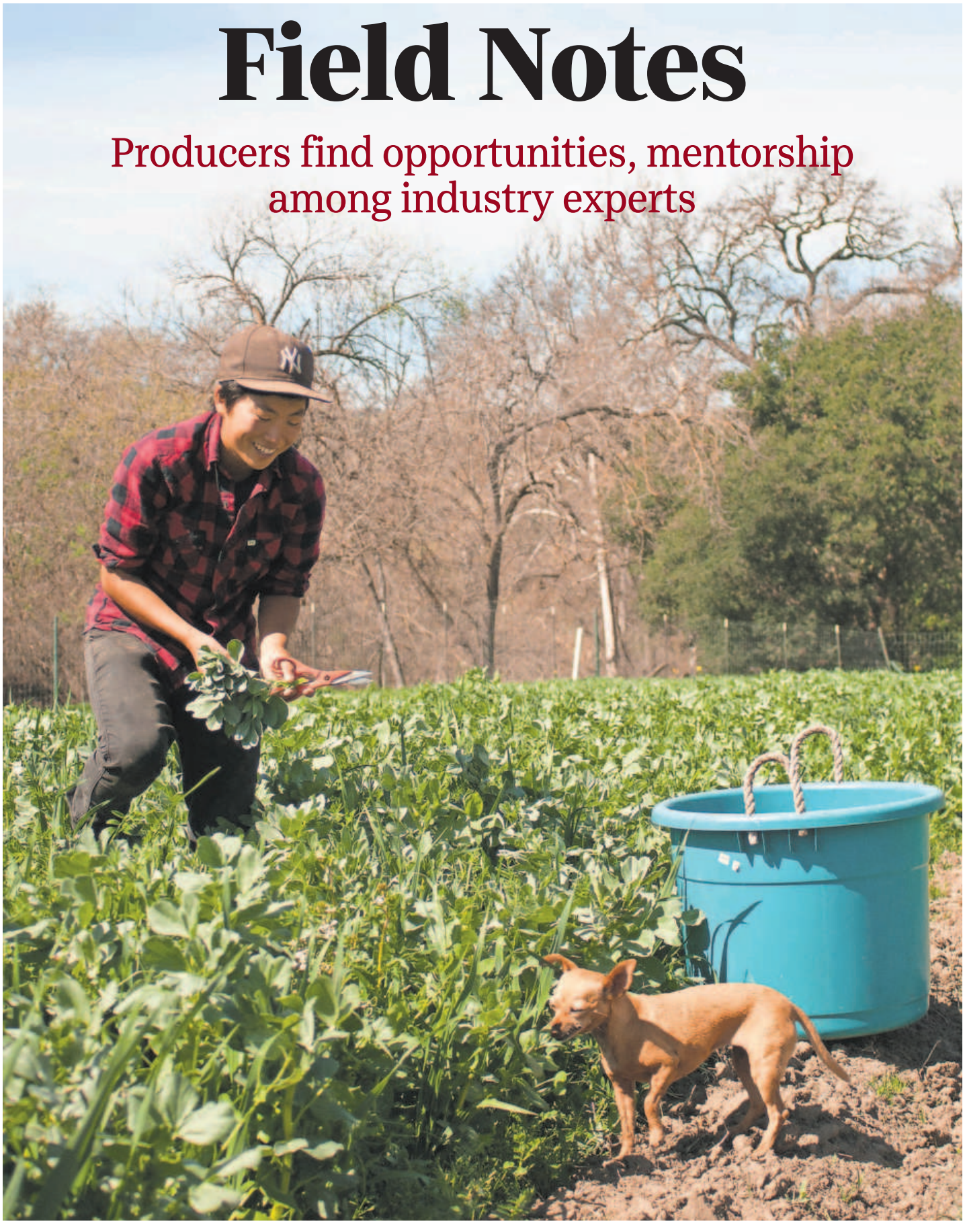

PROVIDED BY NAMU FARM

Kristyn Leach (with pup Bibi) works at Namu Farm in Winters, Calif., which grows produce for Namu Gaji restaurant in San Francisco.

JULIAN VU

By Julia Mitric

KRISTYN LEACH DRIVES A tractor up a field, towing a disc that breaks up remnants of last season's crops so they can mix back into the soil.

Leach and her farm dog, Bibi, look right at home on this plot of land bordered by olive groves in Winters, Calif. She is part of an emergent generation of small California farmers who have horticulture skills, but little or no business background. They are turning to an increasing number of nonprofit programs designed to boost new farmers' success.

"When I started my farm, it wasn't because I felt like a competent businessperson or had any even basic financial

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Farm owner Bertha Magaña found mentorship in David Mancera of Kitchen Table Advisors.

ANDREW NIXON/CAPITAL PUBLIC RADIO

literacy as an individual," Leach said.

Instead, it was her curiosity about traditional Korean farming that launched her on the path to growing vegetables. She even traveled to Korea to learn from an older generation of farmers.

When she started farming 15 years ago, Leach said it was just a "side hustle." But since 2012, she has made her living farming at Namu Farm and growing heirloom Korean and East Asian beans, herbs and melon for the upscale restaurant Namu Gaji in San Francisco. She said that in a way, farming turned her into an "accidental business owner."

Leach is leasing 2 acres from farmer and olive oil producer Mike Madison, who she considers to be her informal mentor. She likes being able to talk shop with him about vintage tractors or how to fix things without spending money.

And Madison said that's the way most farmers solve problems — through one-on-one conversations with each other. Any one particular business training model is not going to cover the many "uncontrollable variables" of farming, he said. "You can get a freak freeze or a wet year, a dry year. The markets are unpredictable," Madison said.

WEARING MANY HATS

A lack of business skills can be an issue for many farmers, noted Evan Wiig, director of membership and communications for the Community Alliance with Family Farmers (CAFF). The nonprofit advocacy organization offers entrepreneurial business training for new farmers and ranchers who want to do small-scale sustainable agriculture. Building up the business acumen of new farmers is a significant issue in California, where nearly a third of the state's farmers are new to the practice. The USDA defines a "beginner" as someone who has farmed for 10 years or less.

Wiig credited the local food movement with attracting new farmers in California. "People are seeking to get out from behind desks and have a better connection to the land and be more entrepreneurial," Wiig explained. "(They) are not exactly drawn by the prospect of sitting behind a computer filling out spreadsheets, crop planning, (doing) profit and loss analysis and developing markets."

But when small farms go under, Wiig said, it's precisely the lack of "some element of business planning" that contributes to their demise.

GET YOUR HANDS DIRTY

The Center for Land-based Learning (CLBL) in Winters, Calif., runs the California Farm Academy Apprenticeship Program with Soil Born Farms of Sacramento.
▸ *landbasedlearning.org*

The School of Adaptive Agriculture in Mendocino, Calif., runs a three-month vocational program for those considering farming or ranching as a career.
▸ *school-of-adaptive-agriculture.org*

GETTING THEIR FEET WET

In 2017, the National Young Farmers Coalition (NYFC) surveyed more than 3,500 young farmers and ranchers across the country and found that more support is needed at the state and federal level, including on-farm apprenticeships and training programs.

In response, several organizations in California recently launched training programs. Kitchen Table Advisors (KTA), a nonprofit funded largely by foundation grants, provides three years of free business guidance for producers on small, organic farms in Northern California and the Central Coast.

David Mancera worked in real estate and finance before becoming a Kitchen Table adviser. Beginning farmers face barriers that can include access to land and capital to run their businesses, he said.

In areas like Monterey, Santa Cruz, San Benito and Madera counties, where he coaches farmers, it's difficult to find 5- to 10-acre parcels for sale, but those smaller sizes are what makes sense for a new farmer, he explained. Several of his clients are former farmworkers making the transition to running their own operations. They can't afford to buy or lease larger parcels, and they're not ready to farm at that scale.

One recent day in Monterey County, Mancera made his way to visit farmer Bertha Magaña. Mancera has been advising Magaña for about three years. She was a sharecropper and nursery worker before enrolling at the Agriculture and Land-Based Training Association in Salinas to study organic farming practices.

"This will be the last harvest of the season, because of the rain," Magaña told Mancera in Spanish. She said she's had a much better yield from this year's strawberries compared to last year.

Mancera began counseling Magaña when she was in the process of purchasing 9 acres in the Royal Oaks area of Monterey County.

Mancera said cash flow management is one of the key things he and Magaña have worked on. He taught her how to use a spreadsheet tool to track transactions; before that she was keeping track of everything in her head.

Still, Mancera conceded that KTA doesn't always see eye to eye with their farmer clients. "We don't tell them what to do," he explained. "We guide them; we help them ask questions. Ultimately, they're the business owners. We're trying to help them develop this business mindset."

This story is part of The California Dream project, a statewide nonprofit media collaboration focused on issues of economic opportunity and quality of life. Julia Mitric writes for Capital Public Radio*, one of several partner organizations including* CALmatters*,* KPBS*,* KPCC *and* KQED*. Additional support was provided by the* Corporation for Public Broadcasting *and the James Irvine Foundation.*

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Kayle Austin credits a loan forgiveness program for her ability to practice rural veterinary medicine.

PROVIDED BY KAYLE AUSTIN

On Call

Colleges are getting creative to help solve a serious shortage of rural livestock veterinarians

By Jodi Helmer

GROWING UP ON A cattle ranch, Kayle Austin remembers her family handling a lot of the minor veterinary care for their 300-head herd.

"In the rural area where I'm from, it was hard to get a vet," said the Colorado native. "There were vets in the area, but we were competing with ranchers that had 5,000 cows; there weren't enough vets to cover such a large area, so you were at the mercy of when the vet could get there."

The situation for small farmers has only gotten worse. Only about 10.5 percent of veterinarians focus exclusively or predominantly on food animals, according to the American Veterinary Medical Foundation (AVMF), and the USDA's National Institute of Food and Agriculture (NIFA) identified 187 (mostly rural) areas where there are too few veterinarians to meet local needs. That means that farmers and ranchers often lack access to medical care for their livestock.

Colleges are stepping up to address the shortage, introducing loan forgiveness initiatives and launching creative programming to boost enrollment in large animal sciences programs and promote careers caring for livestock.

"We need large animal veterinarians in

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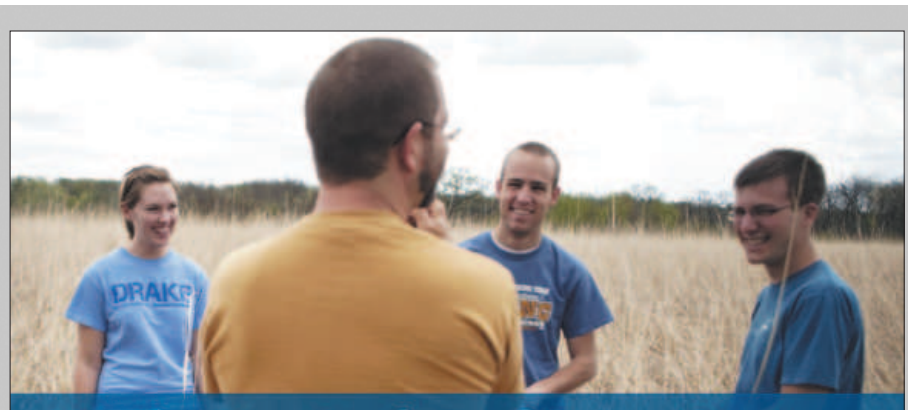

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order to manage herds and herd health," explained Thom Hadley, executive director of the College of Veterinary Medicine and Biomedical Sciences at Colorado State University (CSU). "If we don't focus on the needs of those rural areas, it will impact farmers and the long-term sustainability of our food products. As a college, we need to be doing everything we can to keep as many veterinarians in rural communities as possible."

FUNDING FUELS INTEREST

Christa Finley sought out opportunities to work with cattle to make her vet school application stand out. In the process of working on dairy farms, she fell in love with the work, but concedes that she chose a difficult path.

"It's a hard job," she said. "The weather can be absolutely nasty, and the drive out to some of these farms can be harrowing, and you spend a lot of time knee-deep in manure."

The Bureau of Labor Statistics reported that in 2017, veterinarians in rural areas earned as little as $56,600 — a fraction that vets can earn in urban areas — and graduate with an average student loan debt of $143,757, according to AVMF.

Several colleges have introduced programs to provide loan forgiveness to veterinarians committed to working in rural communities. After graduating from CSU in 2017, Austin started a mobile veterinary clinic to serve producers in northern Colorado. She received $70,000 in loan forgiveness, spread out over four years, through the school's Veterinary Education Loan Repayment Program (VELRP).

CSU secured $140,000 in state funding to launch the initiative last year. Several other colleges, including the University of Minnesota and Kansas State University, offer similar programs. In 2018, the USDA introduced the Veterinary Medicine Loan Repayment Program to contribute up to $25,000 per year toward the repayment of educational loans for veterinarians who agree to work at least three years in the 187 underserved areas that NIFA designated.

Austin, who graduated with $170,000 in student loans, credits the program with making it possible for her to practice rural veterinary medicine: "Financially, I couldn't have gone forward without a program like this to take off that debt load."

But these programs come with restrictions, and Finley — a fourth-year veterinary student at Michigan State University (MSU) — believes that could limit their effectiveness. "A lot of the underserved areas are not attractive for young people to move to being that they are fairly rural and off the beaten path," she said.

Even if loan forgiveness programs can help attract livestock veterinarians to rural communities, keeping them around when the funding period ends remains challenging. Retention is a major issue, according to a 2010 study published in the *Journal of the American Veterinary Medical Association,* which found that 94 percent of rural veterinarians left the field after five years.

INVESTING IN OPPORTUNITIES

Introducing students to opportunities to work with livestock could help attract veterinarians to rural practices, said Ángel Abuelo, assistant professor in the College of Veterinary Medicine at MSU.

"We have less and less of the students that come from a farm or rural background, and it's really common for a majority of students to not have significant exposure to livestock," he said. "We need to do our best to expose students to career options in rural and livestock practices if we want them to work in those areas."

"If we don't focus on the needs of those rural areas, it will impact farmers and the long-term sustainability of our food products."

– THOM HADLEY, executive director of the College of Veterinary Medicine and Biomedical Sciences at Colorado State University

In 2018, USDA awarded MSU and Cornell University a joint $245,500 grant to help recruit and train early-career veterinarians interested in rural bovine health. Students will receive small stipends to participate in externships with rural veterinarians to learn about their practices.

Multiple universities, including Iowa State University and Pennsylvania State University, were part of a group of 2018 recipients that received portions of a $2.4 million grant from NIFA's Veterinary Services Grant Program.

In Pennsylvania, the popularity of raising small poultry flocks has risen, giving way to the highest incidence of human salmonellosis per capita. With

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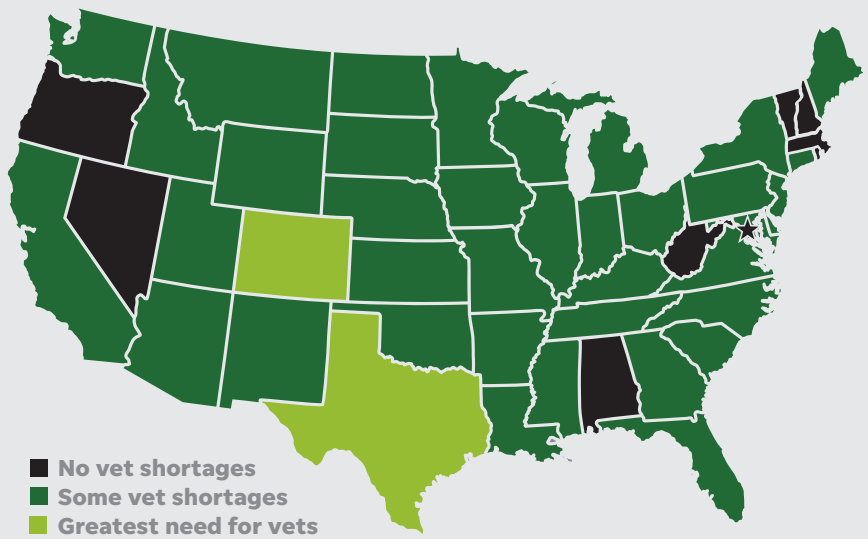
CAELAH DOERR

Michigan State University student Christa Finley said externships that focus on large animals help to supplement vet school curriculum focused largely on cats and dogs.

WHERE ARE RURAL VETERINARIANS NEEDED MOST?

The USDA has identified 187 mostly rural areas that lack sufficient access to veterinarians. Just eight states — Alabama, Massachusetts, Nevada, New Hampshire, Oregon, Rhode Island, West Virginia, Vermont and the District of Columbia — were not experiencing shortages. **Colorado** and **Texas,** each with eight underserved regions, have the greatest need for veterinarians serving rural areas and production animals.



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Many rural farmers handle the majority of their livestock's veterinary needs because of the shortage of available care.

STEPHEN AUSMUS/USDA

its grant, the university provides training to veterinarians working in underserved areas to treat poultry and avoid contamination. Assistant professor Gino Lorenzoni hopes to provide a combination of classroom materials and hands-on training to at least 20 veterinarians per year over the next four years to help ease severe shortages of veterinarians willing to treat poultry. Vets will earn continuing education credits for the classes.

Finley believes the externships will help fill a gap in the curriculum; she signed up to gain more hands-on experience with dairy cows.

"A large component of the (clinical practice) curriculum is small-animal specific; almost all of the rotations that were required — emergency, orthopedic surgery, internal medicine — dealt strictly with dogs and cats," she said.

The sole large animal rotation crams surgery, medicine and dairy practice into a six-week session; a recent requirement to complete a three-week practicum in a rural practice was eliminated after students pushed back, citing a lack of interest in livestock medicine.

"I think that was to the students' disservice because until you do it, it's impossible to say whether or not that's a practice discipline you'd be interested in pursuing," Finley said. "And that's (the purpose) of externships: figuring out what you want to do by experiencing it. It's something we need more of in school if we're going to get more (veterinarians) to work with livestock."

THE PAY GAP FOR RURAL VETERINARIANS

Veterinarians working in rural areas tend to earn lower salaries than their peers in larger cities. Here's how the **annual mean wages** stack up, according to the Bureau of Labor Statistics.

RURAL AREAS
- Central Montana: $56,600
- Central Nebraska: $57,040
- Central Oregon: $60,380

URBAN AREAS
- Trenton, N.J.: $140,890
- El Paso, Texas: $152,730
- Honolulu: $216,240

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ON THE FARM

Farming vs. Food Trends

Is the rise in gluten-free products affecting wheat growers?

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By Kristen A. Schmitt

AMBER WAVES OF GRAIN stretch toward the clear blue Kansas sky. It's mid-July and farmers across the Wheat State are getting ready to harvest the iconic grain. Over the past few years, wheat, once the staple of the all-American diet, has gained increased scrutiny due to the popularity of gluten-free products. In fact, according to a survey released in 2017 by the Mayo Clinic, 3 million people currently follow a gluten-free diet; however, 72 percent of those followers are doing it by choice, not because of a wheat intolerance.

"There's definitely been an increase, but it really isn't healthy for people without celiac (disease) to avoid gluten," said Marilyn Geller, CEO of the Celiac Disease Foundation, a national nonprofit. "Unfortunately, we're still in that viral message stage where gluten-free is considered healthy (for all) even though that's not true."

Geller says that the gluten-free diet is really only beneficial for those with celiac disease — an autoimmune disorder where antibodies attack gluten and cause severe damage to the lining of the small intestine that hinders nutrient absorption. Gluten is a protein found in wheat, rye and barley. Geller added that diagnoses have increased over the past 10 years and now affect 1 in 141 Americans, a widely cited statistic found in a 2012 study in the *American Journal of Gastroenterology*.

Because of this elevated need for gluten-free products, the number of items on the market has grown exponentially. In fact, a study published in August by research firm Technavio found that the global gluten-free market is projected to grow to $9 billion by 2022.

In contrast, over the past two decades, U.S. wheat production has steadily declined. In 1998, wheat farmers produced 2.55 billion bushels of wheat; in 2018, they produced only 1.88 billion bushels, according to the USDA National Agricultural Statistics Service. And, in 2019, wheat production in Kansas, the top wheat-producing state, is predicted to be at its lowest in 100 years.

NEXT STEPS

In 2015, the Kansas Wheat Commission (KWC) began a multiyear study to determine what part of wheat's DNA wreaked havoc on people with gluten

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ON THE FARM

Kansas wheat farmers Louise and Vance Ehmke said the gluten-free movement has not affected their sales.

JERRY GABRIE/PROVIDED BY THE EHMKES

sensitivities. Their goal is to eventually create a "celiac-safe" wheat, "not a gluten-free wheat since the functionality of wheat relies on that gluten to make bread," according to Aaron Harries, vice president of research and operations at KWC. The project is still in its first phase as researchers work to identify specific proteins within the grain that cause the gluten reaction.

"Once we know what those reactive proteins are, it's possible that gene editing could be used to go in and edit those specific proteins out so we could avoid that reactivity," said Harries. "It's not just about selling more wheat. Wheat's a pretty healthy part of a diet, and most people I know with celiac (disease) would love to be able to eat some gluten foods."

3

MILLION

THE NUMBER OF PEOPLE CURRENTLY FOLLOWING A GLUTEN-FREE DIET; 72 PERCENT ARE DOING IT BY CHOICE, NOT BECAUSE OF WHEAT INTOLERANCE

SOURCE: MAYO CLINIC

But Geller noted that it's far better to invest in resources supporting clinical trials for a treatment rather than fund research that culminates in genetically modified products, especially because GMOs are banned in parts of Europe. Nexvax2, a vaccine in development to treat celiac disease, is undergoing the second phase of clinical trials and has been fast-tracked by the Food and Drug Administration. While this vaccine is only for those diagnosed with celiac disease (not those with gluten sensitivity), "the gluten intolerance and sensitivity would be the next logical extension," said Geller.

"We want treatment and a cure," added Geller. "Wheat is still one of the number one crops in the world."

FINDING A MARKET

"There's definitely a legitimate market for gluten-free products," said Vance Ehmke, a fourth-generation wheat farmer. "But as far as having a negative impact on the traditional wheat farmers' income, I'd say that's a real stretch."

Vance and his wife, Louise, farm about 11,000 acres in Lang County, Kan. Every year, they grow 2,500 acres of wheat as well as 2,500 acres each of rye and triticale — a cross between wheat and rye primarily used for cattle forage. They also operate a seed business and sell certified wheat, rye and triticale to other farmers in the area.

"We have hundreds of customers

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ON THE FARM

Since 2015, the Kansas Wheat Commission has been researching how to create a "celiac-safe" wheat.

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that come in August through October, buying seed for their plants," said Louise. "Gluten-free really started taking off about 10 years ago — and, in the last five years, not one customer has ever said this gluten-free thing is really bothering me."

Bob's Red Mill, one of the leaders in gluten-free flours and other baking agents, was an early entrant into the gluten-free market, putting its first "celiac-safe" flours on grocery shelves in 1983. However, the company produces both gluten-free and gluten-based products and works with farmers to grow a variety of different grains.

"The spike in gluten-free products and the want in gluten-free products hasn't necessarily hurt the farmers we work with because the wheat industry in America is vast and the gluten-free industry is so relatively small in comparison," said Sophia Malek, culinary nutritionist for Bob's Red Mill.

Malek acknowledged that the gluten-free trend results in the desire to produce more gluten-free — and even grain-free — products for the specialty market, but said that Bob's Red Mill doesn't plan to scale down its whole-wheat flour production or shun other whole-grain products like farro.

"The decrease in wheat production in the U.S. is more in response to global production of wheat," said Harries. "More wheat is being produced in the world every year. It's no longer just a U.S. crop."

Russia, for example, once a large buyer of U.S. wheat, is now the nation's largest export competitor, according to Harries. This role reversal shifts the profitability for U.S. wheat farmers. To offset this loss, many farmers plant corn and soybeans because there are better subsidies and, overseas, the demand for soybeans is higher, equaling more income for farmers, said Harries.

To Vance, it's a simple lesson of supply and demand. "If a farmer can't make any money doing something, that farmer is going to quit doing it and do something else. If they're not producing wheat, the surplus shrinks."

Wheat will always be part of the equation, though. "On our farm, we have absolutely and totally diversified away from wheat to other niche crops like rye and triticale," he said. "We may make more money growing those other crops, but wheat is still the backbone of the Kansas agricultural economy."

THE MYTH OF HEIRLOOM WHEAT

Despite being touted as "better" or "safe" for those with gluten intolerance or sensitivity, heirloom wheat is still wheat. In a recent study published in the *Journal of Cereal Science*, researchers concluded that "ancient wheats differ little from modern wheat species" aside from having a lower level of dietary fiber.

"At a molecular level, the proteins are pretty much the same," said Aaron Harries of the Kansas Wheat Commission. "We try to get more protein in wheat when we grow it because that's a value, and it makes better bread, but the actual structure and makeup of those proteins have really never changed."

Turkey Red, considered a heritage wheat, was first brought to Kansas in the early 1870s by Mennonite immigrants from Russia, and it became a prominent crop in Kansas between the 1920s and 1940s. Kansas farmers Vance and Louise Ehmke grow the niche variety and often sell it either one bushel at a time or, sometimes, by the pound. "We get calls from all over the country," said Vance. "People want to grind their own flour or make their own beer or whiskey."

Louise speculated that Turkey Red regained its popularity a few years ago when a *New York Times* article claimed it was healthier for those with gluten intolerance and sensitivity.

"Wheat is wheat," she said. "People think that by growing this ancient grain and making flour for themselves, that they aren't going to get the allergens or problems. There's no science in that."

— Kristen A. Schmitt

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ON THE FARM


Dietrich Gehring of Indian Ladder Farms and farm manager Tim Albright


In 2018, Laura Ten Eyck, her husband, Dietrich, and their son, Wolfgang Gehring, pictured, started growing hemp on their New York farm.


Laura Ten Eyck

LAURA TEN EYCK (2); BRIE PASSANO (2)

A Budding Business

Hemp could be agriculture's next big industry

By Deanna Fox

ON LAURA TEN EYCK'S century-old farm, a 6.5-acre plot just beyond her farmhouse doorstep will soon be planted with a second crop of hemp, bringing with it hope for a new boon.

She is the fourth generation in her family to run Indian Ladder Farms, based in Altamont, N.Y., and she continues the legacy of agricultural advancement set in motion by her predecessors. Her great-grandfather — a U.S. congressman and New York state commissioner of agriculture in the 1920s and 1930s — started the farm as a dairy and milk delivery service.

By the 1970s, Indian Ladder focused primarily on growing apples, was an innovator in developing new rootstock varieties and was mass-producing cider doughnuts. And over the past decade, Ten Eyck and her husband, Dietrich Gehring, began growing hops and malting barley, opening a brewery and hard cidery. In 2018, they jumped into the emerging market for industrial hemp, now nationally legalized under the 2018 Farm Bill.

Hemp and marijuana are both in the cannabis family and look and smell alike, but are chemically and structurally different. Hemp plants contain virtually

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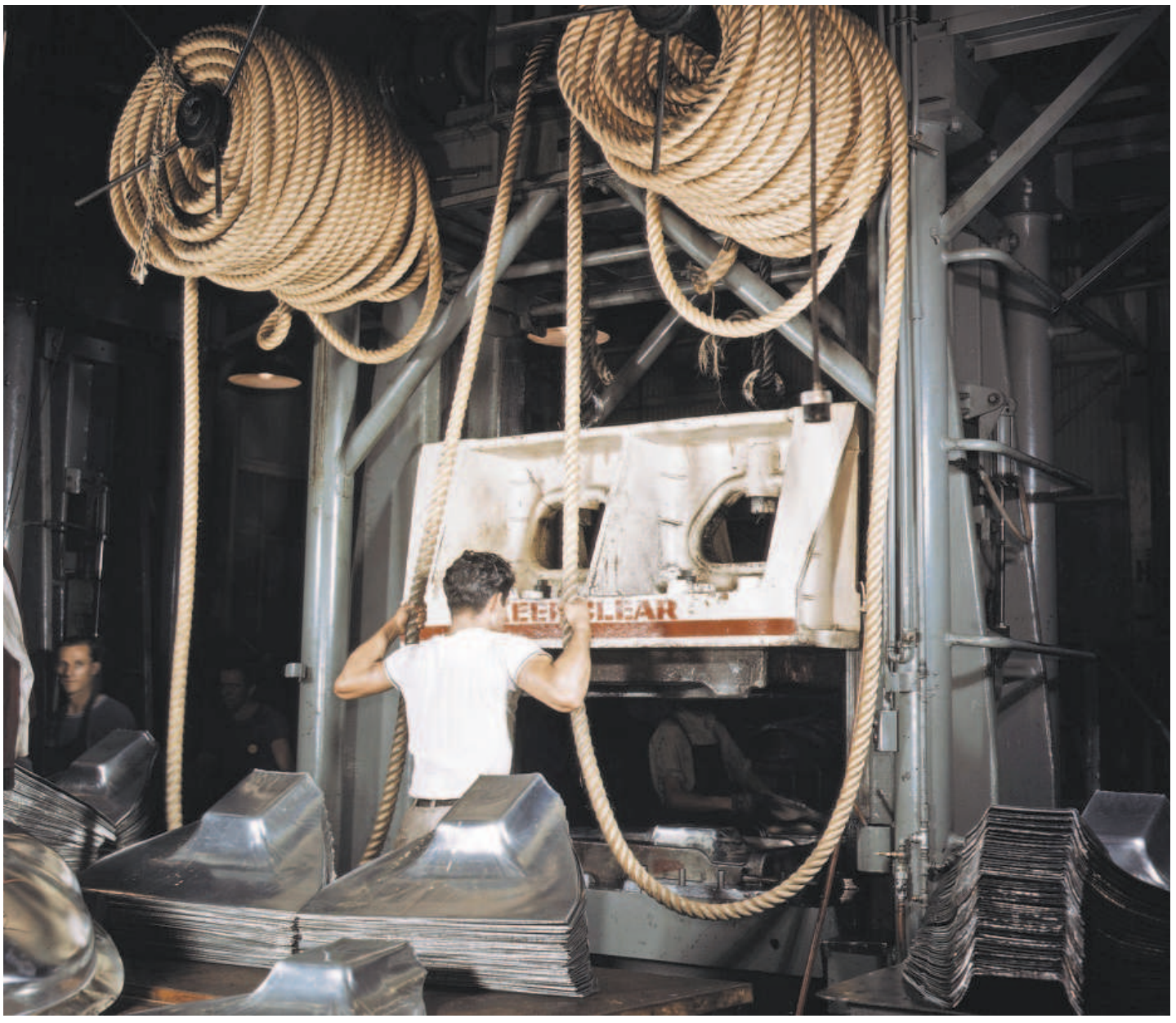
ON THE FARM



UNIVERSAL HISTORY ARCHIVE/UIG VIA GETTY IMAGES

A factory worker pulls a hemp rope while manufacturing sheet metal parts in 1942 for United Nations bombers and fighter planes at North American Aviation Inc., in Inglewood, Calif. Hemp was grown widely across the U.S. during World War II.

none of the psychoactive compounds that get people high the way marijuana does. Hemp fibers have long been prized for their durability and use in clothing and paper, and hemp plants are increasingly used to make food and other dietary supplements containing cannabidiol (CBD), a cannabis derivative that supporters say has important health benefits. Hemp has a range of uses across dietary supplements, personal care, cosmetics, bioplastics, biodiesel, paint and industrial solvents. The *Hemp Business Journal* estimates at least $820 million in hemp products were sold in the U.S. in 2017, and that amount is expected to reach $1.9 billion by 2022.

"I don't know if it is genetic or what, but we like to experiment," said Ten Eyck, referring to growing hemp. "It's a potentially very lucrative crop. When there is a crop that has potentially high value in agriculture, that is appealing." When her great-grandfather first started farming on the familial land, hemp was still legal in the U.S. In the century since, hemp had all but been completely eradicated from the American farmscape.

A COMPLEX HISTORY

Farmers in early 1900s Jamestown, Va., were instructed by King James I to grow hemp for export, and it was grown until the 1930s, when it was on the precipice of becoming a billion-dollar crop. But the passing of the Marijuana Tax Act of 1937 placed a tariff on cannabis and effectively killed the hemp industry. However, during WWII in 1942, the USDA's grassroots campaign and film, *Hemp for Victory*, encouraged farmers to grow it to make the cordage used in ships' rigging, which was typically imported from Manila, Philippines. Hundreds of thousands of acres of hemp were grown across the U.S., but in 1957 it was banned from commercial cultivation, and in 1970 was classified as an illegal Schedule 1 drug by the Controlled Substances Act, further stamping out options for growers.

Today, hemp can be grown across the

Because there's no large-scale hemp cultivation in the U.S. yet, the products sold here are primarily grown from seeds harvested in Canada, Europe and China. Canada supplies about 90 percent of the hemp products sold in the U.S.

U.S. The 2018 Farm Bill, which passed in December, widely legalized the growth of hemp and builds off the 2014 Farm Bill, which allowed for de facto legislation for industrial agricultural research. States used this prompt to explore hemp production, resulting in more than 25,500 acres of the crop in 19 states by the end of 2017. Globally, the hemp market consists of more than 25,000 products in nine submarkets: agriculture, textiles, recycling, automotive, furniture, food, paper, building materials and personal care. Most domestic hemp is used for CBD oil, hemp seed oil and agricultural seed.

Small farmers like Ten Eyck were able to apply for state-sponsored growing permits. Growing hemp appealed to Ten Eyck, in part, because she was already cultivating hops, which are closely related. "We were curious in a potential future crossover with the brewing industry," she said.

Ten Eyck grew her first crop of hemp in cooperation with researchers at State University of New York at Morrisville (SUNY). Regulations from liquor authorities and the U.S. Alcohol and Tobacco Tax and Trade Bureau prohibit her from both producing beer and growing hemp under the Indian Ladder Farms masthead, so her hemp field is on private land adjacent to the farm.

Ten Eyck cautioned, however, that farming hemp is not something that should be casually dabbled in. "It's not easy for a nonfarmer to grow hemp. It's fussy. People think they can grow it to just be part of the industry as a consumer, not a farmer. They don't have the full appreciation for the complexity of farming." The lack of knowledge and infrastructure for growing hemp stymies the blast-off of the industry, she added. "We are starting from way behind the start line."

One of the biggest issues is that con-

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ON THE FARM

SARA SOFIA WALLACH

Harvested hemp at New York's Old Mud Creek Farm waits to be broken down and hung to dry for use by the Hudson Hemp company.

versations about the legalities of using hemp have eclipsed the agricultural discussions, making advancements difficult.

PAVING THE WAY

Kentucky was a leader in pushing for hemp legalization to replace the waning tobacco industry. Hemp production in that state was authorized in 2013 and funded in part from Tobacco Master Settlement Agreement funds. Geoff Whaling, board chairman for the National Hemp Association, said that Senate Majority Leader Mitch McConnell, a Kentucky senator, as member of the Senate Agriculture Committee, was instrumental in pushing for the 2014 and 2018 Farm Bill allowances for hemp. Other senators from hemp-producing states — North Dakota, New York and Minnesota — were also instrumental in the passage. Whaling said the crop insurance and research potential granted with the 2018 Farm Bill allows for new and existing farms to make a two- to three-year commitment to growing hemp and explore the opportunities for domestic hemp production. Currently, he said, there is a $600 million market for seed in the U.S., most of which comes from Canada but could be produced domestically.

The next state poised for a hemp boom is New York, Whaling said, which works out well for Ten Eyck. With statewide legislation and framework in place for a rapid increase in production and a dedication to funding the crop, he expects New York will soon be a leader in small farm-based hemp harvesting.

In New York's Hudson Valley, Hudson Hemp was one of the first companies authorized to cultivate and process hemp in the state. The company currently sells two products: a broad-spectrum hemp oil (the distillate produced from hemp flowers) and CBD isolate (a powdered product). While CBD oil is made from processing the flower and leaves of a hemp plant, hemp seed oil is expeller- or cold-pressed from the seeds of the plant.

Hudson Hemp sources mainly from its Old Mud Creek Farm, which uses regenerative agriculture practices to grow hemp on 40 of its 2,400 acres. The company, which follows USDA organic practices, also processes the crop from four affiliate farms in New York.

"Hemp offered itself as a beautiful addition to our (crop) rotation. There is so much you can do with it," said Melany Dobson, chief brand officer of Hudson Hemp. She added that the market was already competitive, and the widespread legalization will increase that competition but will create enough industry opportunities to allow growers to flourish.

RIPE FOR EXPANSION

"Hemp is an industry just being born," noted Doug Fine, author of *Hemp*

CONTINUED »

GETTY IMAGES

CBD, HEMP'S RISING STAR

While cannabidiol (CBD) is present in marijuana, most CBD oil is extracted from hemp, which only contains trace levels of the psychoactive compound delta-9-tetrahydrocannabinol (THC). (Marijuana is comprised of up to 30 percent of THC.) CBD works within the body's endocannabinoid system, which regulates a state of balance in the body and can affect sleep function, mood, pain regulation, hormones and immune response.

Often sold in oil form, CBD can also be found in a wide range of products including body lotion, face serum, olive oil, bath scrub, cold-brew coffee, sports salve, infused water and gummy snacks. Companies typically refer to hemp-derived CBD as "hemp extract," "hemp oil," and "hemp complex" in the ingredient list.

Laws surrounding the sale of hemp CBD are murky at best; products made with the cannabinoid are not legal in all 50 states, though the oil is legal in more states than medicinal marijuana.

The Food and Drug Administration requires any cannabis product (hemp-derived or otherwise) claiming therapeutic benefit to be approved. Thus far, the only FDA-approved use of CBD is Epidiolex, a drug that treats seizures associated with two forms of epilepsy.

— Carly Mallenbaum

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Bound: Dispatches from the Front Lines of the Next Agricultural Revolution. The entrepreneur farms and consults about hemp internationally. He pointed to the enormous growth that has occurred since 2014 as evidence of the crop's viability: "Any industry would be impressed with a double-digit growth rate."

Because there's no large-scale hemp cultivation in the U.S. yet, the products sold here are primarily grown from seeds harvested in Canada, Europe and China, according to federal officials. Canada supplies about 90 percent of the hemp products sold in the United States.

Whaling predicted that more U.S. farmers will incorporate hemp into current crop rotation once the properties of the plant are promoted and farmers and consumers become increasingly educated. Hemp takes 110 days to mature for harvest from seed, absorbs three times more carbon dioxide from the air as any other crop, adds nitrogen into the soil while removing toxins, has both a tap root and feeder roots that help prevent soil erosion, and suppresses weeds, Whaling said. Hemp potential ranges from a winter cover crop for small produce farmers to large-scale production to compete with wheat, soy, corn and cotton.

Both Fine and Whaling noted that the biggest issue with hemp is the current supply chain. Whaling said that harvesting equipment and processing centers are few and lacking. Fine believes that these early stages in domestic industrial hemp mean that harvesting and processing can be done on a small, regional scale that keeps wealth local. "We can develop products locally and employ the accelerator effect. We have the opportunity today to regionalize distribution and create a lucrative living to entire communities," said Fine.

Advocates say the 2018 Farm Bill will unleash broader cultivation and processing nationally. You can already buy hemp dog treats, hemp-infused beer and hemp lotion, and in Colorado, New Belgium Brewing, which makes the nationally available The Hemperor HPA, plans to explore brewing with hemp flowers. The clothing and outdoor gear company Patagonia, which already makes hemp-based clothing using imported fibers, plans to increase its use of American-grown crops. "We look forward to buying hemp from Colorado and the United States to sell in our stores," said Mark Stevens, one of the company's district environmental coordinators.

For Whaling, the uses of hemp are endless: "As the hemp industry takes off, more people will turn to hemp."

PETER CROSBY

Melany Dobson, chief brand officer of Hudson Hemp, stands in a hemp field at Old Mud Creek Farm in New York. The company partners with farmers to source the crop.

AMANDA GORSKI

Now that hemp is legal to grow again, author and hemp farmer Doug Fine believes the crop has the potential to become America's newest billion-dollar industry.

HIGH EXPECTATIONS

After the 2018 Farm Bill reclassified hemp as an agricultural product, the door swung wide open for all commercial growers. And the potential of the crop has piqued the interest of many. It grows more vigorously than corn, but doesn't need as much water, fertilizer or spraying.

Hemp Industry Daily, which covers financial, legal and B2B news, released a 2018 report that detailed information on the nation's top 10 hemp-growing states. Here are the top five:

1. Colorado
It's no surprise that more than half of the nation's 2017 production occurred in Colorado — there are a whopping 386 growers in the state. In 2012, voters authorized hemp production, and the state has been on an upward trajectory ever since.

2. Kentucky
Thanks to its hospitable climate, hemp-friendly regulations and a well-oiled processing infrastructure, Kentucky comes in at a strong No. 2 with lots of room for growth.

3. Oregon
Because a 2017 law requires hemp producers to test their products as stringently as marijuana, hemp products from Oregon will be food-grade quality and tested for pesticides and contaminants. These regulations could help position the state for national dominance.

4. North Dakota
Although drought plagued growers in 2017, there are more than 3,000 acres of hemp in active production. The state is also known for its exceptional system for providing seeds to interested growers.

5. Minnesota
Hemp varieties already thriving in Canada do well in this state, which has an abundance of wild hemp descended from World War II-era crops.

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ON THE FARM

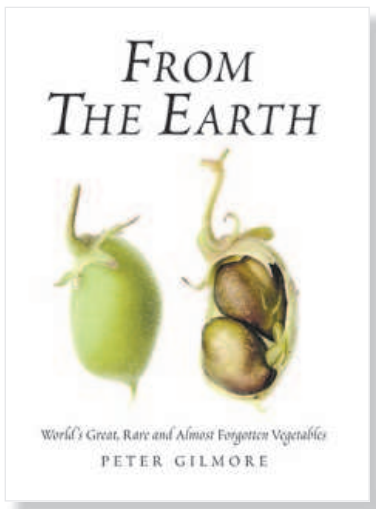
From Seed to Plate

Chef's book chronicles diverse heritage of heirlooms

By Sara Schwartz

THERE'S COUNTRY GENTLEMAN SWEET corn, which delights with its zigzagging white kernels. The Fastigiata pin-striped peanut, originally from Ecuador, surprises with its striking maroon and white pattern. And the black chickpea turns a daring onyx only after the seeds have been fully dried.

It's finds like these that award-winning Australian chef Peter Gilmore chronicles in his expansive book, *From the Earth: World's Great, Rare and Almost Forgotten Vegetables.* Spurred to expand the dish diversity in his two Sydney restaurants, Bennelong and Quay, Gilmore began planting and researching heirlooms and open-pollinated varieties of vegetables and fruit. Focusing on flavor and heritage, he paired each one with a gourmet recipe, crafted to draw out the culinary potential of every heirloom.



"I could've easily written a book about 200 heirloom vegetables. It was hard to narrow down," Gilmore said, of choosing the 50 varieties. "There are a lot of really incredible, unusual vegetables out there, but they also had to be incredibly tasty and work within a recipe."

His mission took him around the world, tracking down varieties sometimes known only to a few, like Italy's Umbrian wild pea, which was saved by a group of devoted locals from being lost forever. "I actually was in Italy, and I ended up finding them in a gourmet store over there, just a small packet, and that's how I eventually got them — I couldn't get them from any seed company."

Gilmore's location is especially advantageous: "The beautiful thing about the Australian climate is that we've got a lot of very diverse growing regions," he said. "I probably grew about 70 percent of the vegetables myself personally where I live in Sydney, and I also have a lot of growers who grow a lot of things for me."

In *From the Earth*, Gilmore's passion for preserving the rare and almost forgotten is infectious, so don't be surprised if you find yourself hunting down Gete Okosomin squash or Kyoto red carrot seeds — it's only natural.

"Saving seeds has become a bit of an obsession now for me," Gilmore said. "It gets in your blood a little bit."

Fastigiata pin-striped peanut

Country Gentleman sweet corn

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