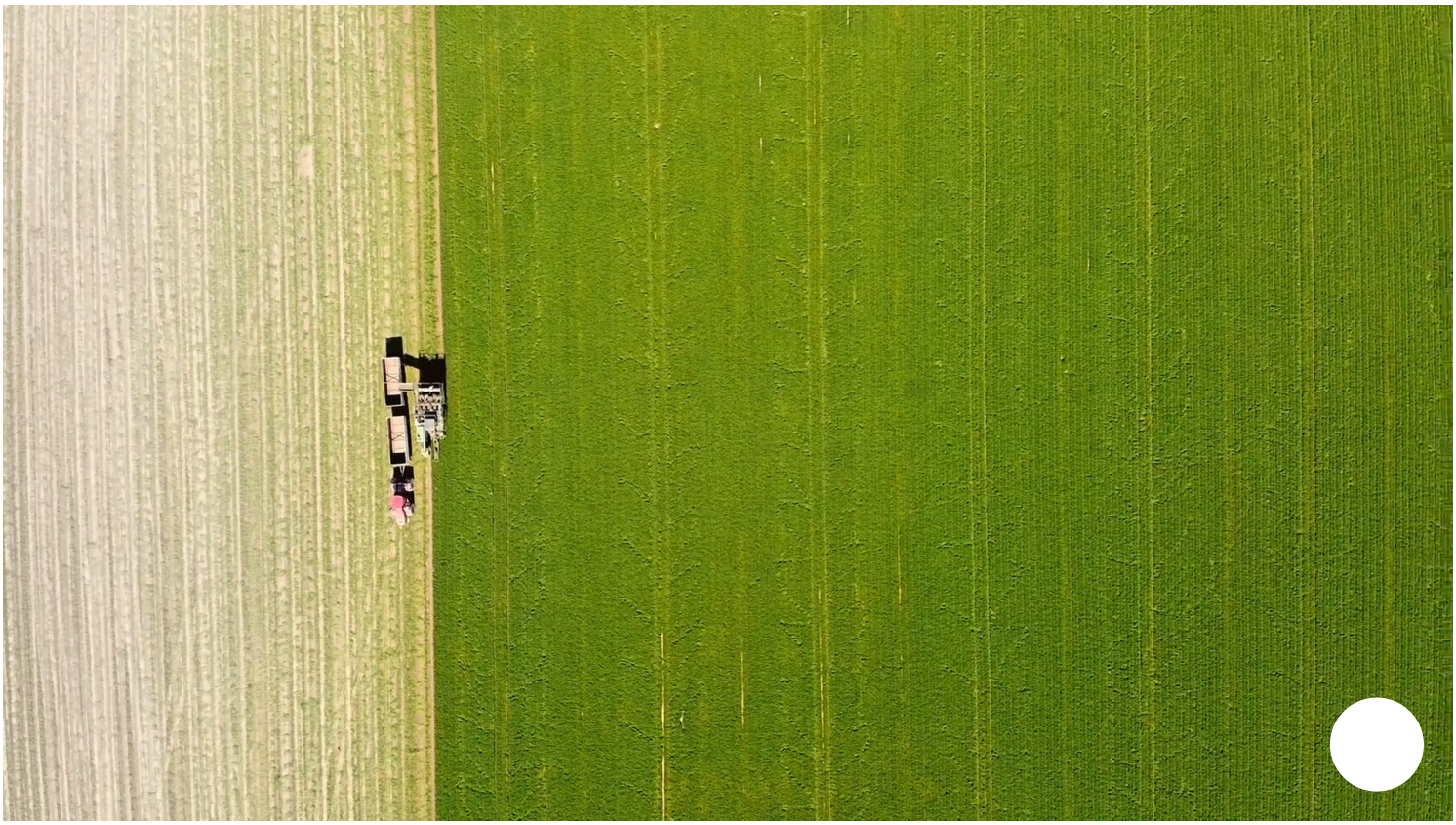


24%: The portion of global greenhouse gas emissions generated by agriculture and forestry. VIDEO: CODY COBB

EMMA MARRIS SCIENCE 04.01.2020 06:00 AM

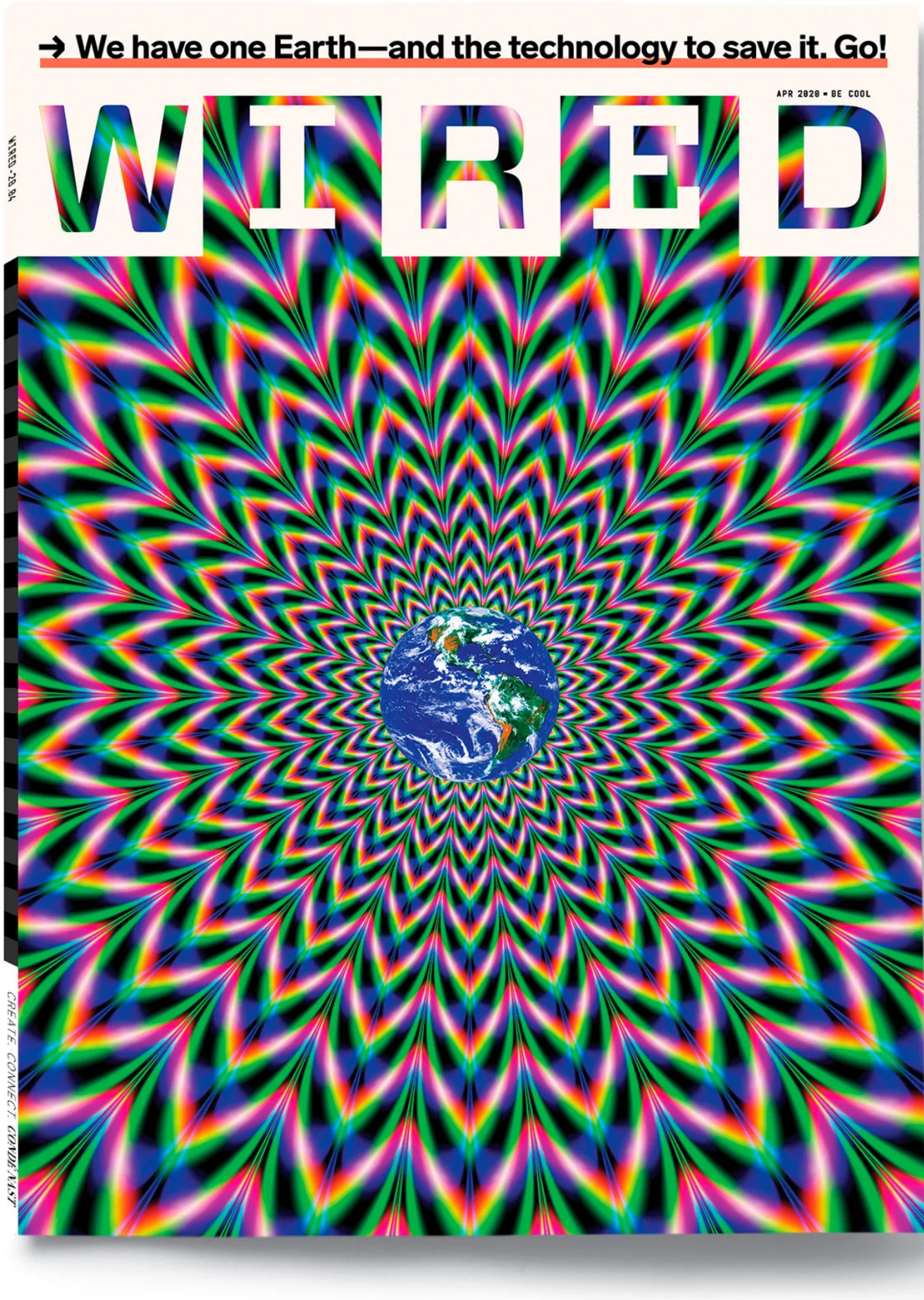
GMOs Could be a Key to Sustainable Farming

If we want to feed a growing population without fueling global warming, we need to redefine what we think of as good food.

SOMEONE ONCE TOLD me you could survive on just peanut butter sandwiches and oranges. I have no idea if that's true, but the advice suggested a tasty lunch for a road trip. It was a freezing, foggy day last December, and I was preparing to drive from my home in Klamath Falls, Oregon, to California's Central Valley, the great agricultural heartland of a state that

produces a third of the country's vegetables and two-thirds of its fruits and nuts. As I spread my peanut butter, I read the packages on my counter. My nine-grain bread promised, vaguely, that it was “made with natural ingredients.” My oranges were “locally grown.” My peanut butter jar assured me twice, once on each side, that the spread was “NON GMO.” It was even “CERTIFIED NON GMO.” The inspection must have been a rather cursory affair, given that there are no genetically modified peanuts on the market.

The grocery aisle is a testament to our attachment to “natural” as a signifier for all that is good. And as many consumers become increasingly concerned about global warming, there's a tendency to assume that these same labels also mean a product is good for the planet.



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But unfortunately, the packages on my counter and elsewhere in my kitchen, like my fancy organic sauerkraut ("Our passion for healthy, natural living is reflected in all our products"), told me very little that was relevant to climate change. My bag of local (that is, California) oranges presumably required less fossil fuel to get to my store than if they'd been from Mexico or Spain. But beyond that, I knew nothing.

Some labels—like "natural"—don't mean *anything.* A USDA organic certification is meaningful: It says the food was grown without certain forbidden synthetic chemicals and wasn't genetically modified. But the label in no way guarantees that the food was grown in a manner best for the climate. For one thing, many organic crops use more land than their conventional counterparts. When you clear land for crops, you often cut down forests—destroying a valuable carbon sink and turning it into a carbon leak. On the other hand, some conventional farming techniques use less land but rely on artificial fertilizer, which can make its way into the atmosphere as a potent greenhouse gas called nitrous oxide.

Which foods generate the fewest emissions? No federal certification will tell me that. And what's worse, even when consumers are presented with information relevant to climate change, they seem blind to it. One study suggested that, on average, "sustainability-conscious" American consumers will pay $1.16 more for a package of organic coffee, but they won't pay a premium for a less familiar "Carbon Footprint" label that quantifies the emissions associated with the product. This may simply reflect how 20 years of the organic label have conditioned public consciousness, but it also suggests something else: that our moral intuitions about food are out of whack with the demands of a crisis that is right on top of us.

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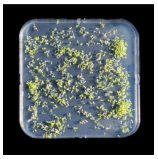
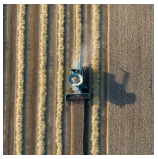


CLIMATE CHANGE

Crispr Can Help Solve Our Looming Food Crisis—Here's How



FALLOW FIELDS

The Midwest's Farms Face an Intense, Crop-Killing Future

UNCATEGORIZED

Organic GMOs Could Be The Future of Food — If We Let Them

This is a problem. Agriculture, including livestock and forestry, accounts for 24 percent of human-generated greenhouse gas emissions. We face a formidable challenge in the years ahead. We need to reduce those emissions and also sustain a growing population in a world of increasingly extreme conditions. And it would be nice if we could do it without expanding agriculture's footprint, so the rest of Earth's species can live here too.

To do so, we're going to need to abandon some of our attachment to what we perceive as natural, and not just at the supermarket. After all, we're not going to stop global warming merely by chasing after premium versions of food that only a few consumers can afford. We need to revise our thinking about food so that, as citizens, we can push for the regulatory policies that will meaningfully shift our entire food system's effect on the climate.

For my money, this system won't look like today's organic or today's conventional, but an evolving mix of both. As it happened, some important people—farmers and scientists—willing to cross these ideological lines lived not too far away. In looking around for people who are thinking deeply about climate change, I'd heard about Don Cameron, who farms a mere 7 hours and 45 minutes south of me. Hey, it's the West. That's practically a day trip.

Don Cameron, general manager of Terranova, stands in a field of carrots. His dream: drought-resistant crops. PHOTOGRAPH: CODY COBB

SANDWICHES PACKED, COFFEE thermos filled, I kissed my two children and husband goodbye and headed south on US Route 97, out of the high desert basin where I live. Many hours later, as I approached Fresno, the landscape had flattened and dried out considerably. I'd eaten three sandwiches, several oranges, and finished my coffee. Early the next morning, after a night in a hotel, I drove through the darkness to Terranova Ranch. This farm, where Cameron is the general manager, sprawls over 6,000 acres in the already hot and dry San Joaquin Valley, an expanse that is expected to become 4 to 6 degrees warmer by the end of the century.

At the appointed hour, I showed up at the farm shop, where workers were gathering for the day, snacking on fresh almonds and joking in Spanish. Cameron, silver-haired in cowboy boots and fleece vest, suggested a tour of his operation in his Range Rover Sport. Terranova grows about 20 different crops. You may have munched on its pistachios; its red jalapeño peppers

end up as Huy Fong's Sriracha sauce. The farm grows most of its food conventionally, but 950 acres are organic.

Driving by the fields, I was struck by how blurry the lines were between Terranova's organic and conventional operations. Cameron grows certain crops organically in part because they pay better, but he has also incorporated some organic techniques into his conventional side because they work. Using chicken manure as fertilizer helped him add phosphate and potassium to his soil; owl boxes provide him with chemical-free gopher control.

Climate change is on Cameron's mind every day, he told me, because nearly every part of his operation is changing as a result. It was December, but splashes of red peppers missed by a recent harvest still lit up the fields. “We've been growing peppers late in the fall,” he said. Ten years ago, they finished the harvest in September or October. “Falls are warm and springs are earlier.”

Early hot days have begun to kill some of his tomatoes, and he's looking for new varieties that can take the heat. He worries about his pickers in midsummer. “We don't want them to get heat sick.” One Fourth of July, Cameron picked peppers for a shift, taking over from an older woman who was feeling ill. “I picked for an hour; I thought I was going to die.”

When I asked Cameron what new tools or technologies would help to cope with climate change, the very first thing he said was “drought resistance.”

Worsening droughts are putting pressure on water in the valley. Groundwater levels are falling, and, to cope, Cameron has installed huge pumps, pipes, and channels to move water from the periodic floods on the Kings River onto his almond orchards and to recharge his aquifer. But what he really wants are crops that can thrive with less water, and he isn't too particular about whether they are bred the old-fashioned way or genetically modified.

In later winter many of the fields in the valley were expanses of bare, sandy earth; but along the edges were a few flourishing green shrubs, about knee-high. These were Russian thistles, better known as tumbleweeds. (Later, they will mature, detach, and roll away to disperse their seeds.) These plants, native to Eurasia, slipped into America with imported flax seed in 1873 and have thrived across the West. Cameron pointed to one of the bushes, emerald green

without irrigation or tending. “That thing grows with no water,” he said. “There's a gene out there that could really help us.”

Cameron's almond orchards are irrigated by water from floods on the Kings River. PHOTOGRAPH: CODY COBB

IN OTHER PARTS of the warming world, drought is the least of farmers' worries: They struggle with too much water, not too little. Rice—the staple of more than half of humanity—grows in water, but it's finicky. While rice roots are happy underwater, the plant's leaves can't tolerate it. (Seedlings need to be transplanted into flooded paddies at the right point in maturity.) A flood that covers the whole plant will kill it.

In Davis, California, 190 miles from Terranova, I met up with Pamela Ronald, a plant geneticist at UC Davis who has worked to solve this problem. Climate change is making floods worse in parts of South Asia, and in 2006, Ronald helped create a kind of rice that can survive submersion in water. By 2017, some 6 million farmers in Bangladesh, Nepal, and India were

growing this rice. We talked in her cozy office, where a painting hangs on the wall of a man under a deluge of rain struggling to plow a field.

The history of agriculture is all about human intervention, taking plants and breeding them to produce a better yield or tastier fruit. Ronald sped up this process by using molecular tools to identify the genes that allowed a low-yield rice to withstand floods. Colleagues at the International Rice Research Institute in the Philippines then bred the submergence-tolerant variety with popular high-yielding varieties. They used genetic markers to screen the resulting offspring when they were seedlings, keeping only those with the right genes.

Plants are the staff of life. With help from scientists, they could also help cool a warming planet. A few examples at various stages of development:

1. The Land Institute is starting to commercialize a perennial wheat that doesn't require soil tilling, a process that releases carbon into the atmosphere.

2. Researchers at the Salk Institute want to encourage crop plants to grow roots that are rich in suberin, a substance that gloms onto carbon, and reach deeper into soil where the carbon can be stored.

3. Researchers at various universities are trying to figure out how to make cereals produce their own nitrogen, meaning no need for fertilizers and their emissions.

This creation, Sub1 rice, is not considered a GMO by many definitions, because no genes from other species were inserted into the plants. But Ronald encourages genetically engineering crops if it can do anything to mitigate climate change or help low-income farmers. “You want all the options on the table for climate,” she says. She points to a transgenic form of eggplant that is also a hit in Bangladesh. It contains a gene from a bacteria that allows the plant to repel a particularly destructive moth larvae, which is thriving in a hotter world. Farmers who plant

this GMO eggplant variety are able to cease sometimes daily applications of toxic and expensive pesticides.

Affluent, environmentally conscious shoppers often shun GMOs, as any stroll down a Whole Foods aisle will attest. Organizations of organic farmers have generally fought to prevent GMOs from getting an organic label, even for traits like drought tolerance. Critiques generally fall into three camps: the often high cost of engineered seeds, concerns about herbicides sprayed on herbicide-resistant GMOs, and vague worries about safety. As far as the first criticism goes, it is true that some GMOs require farmers to pay each year for expensive seeds, but that cost does not apply to crops developed by a nonprofit (as Sub1 rice was). The second applies only to the subset of GMOs that are engineered to tolerate glyphosate herbicide. (And to confuse things even more, some of the herbicides used before were arguably worse.) As far as safety goes, decades of scientific research has shown there's nothing especially different about genetically modified crops in terms of health or safety.

While most GMO crops are still either herbicide tolerant or pest resistant, more climate-change-ready traits are beginning to roll out. North American farmers are already planting corn engineered to be drought tolerant, though the seeds have mixed reviews. Genetically engineered drought-tolerant soybeans have been approved in the US, Brazil, Paraguay, and Argentina—where they are expected to be planted later this year. Corn engineered with drought tolerance and insect resistance for smallholder African farmers, funded by charitable entities, is aiming to be in farmers' hands by 2023.

With new, precise tools like Crispr gene editing, the potential is enormous. In addition to drought and heat tolerance, crops could be engineered to increase yields (and thus reduce agricultural footprints) and to be resistant to the pests and diseases that thrive in hotter climates.

The way Ronald sees it, we are in a crisis that demands every possible tool. Imagine that one of your loved ones had a virulent cancer, she says, and the most effective medicine was one that had been engineered in a lab. “You would never pull an option off the table because it was genetically engineered,” she says. Why would we do so for our planet?

Pamela Ronald and Raoul Adamchak argue that genetic engineering and organic crops do not have to be at odds. PHOTOGRAPH: CODY COBB

AFTER A SHORT walk through the UC Davis campus, I met up with Raoul Adamchak—bearded, bespectacled, and clad in overalls and a wide-brimmed hat. Since 1996, Adamchak has overseen the Market Garden at UC Davis. He cares for seven picture-perfect organic acres with a rotating crew of undergrads. The core of organic farming, he says, it to nourish soil with composts and manures, cover crops, and creative crop rotations rather than unhealthy or environmentally damaging chemicals.

As students washed purple carrots and sorted ruby-red beets, I helped Adamchak harvest a few rows of gai lan, a slender vegetable with yellow blooms. Organic farmers and geneticists tend to live in different ideological universes, and there's little trust between them. But Adamchak thinks GMOs should not be banned from the organic label. If Adamchak has managed to be more open-minded, it may be because he spends a significant amount of time

talking to one particular crop scientist: Pam Ronald, his wife, with whom he wrote *Tomorrow's Table*, a plea for a detente between the sides.

The combination of GMO crops and organic farming methods, he says, could be particularly powerful for farmers on small plots in low-income countries. If staples like corn could be engineered to fix their own nitrogen, resist pests, and survive heat, cash-strapped farmers wouldn't have to buy inorganic fertilizer or pesticides. And they wouldn't starve as the climate warms.

GMOs aren't the only solution, of course, especially for many parts of the world that would benefit more quickly from solar-powered irrigation or other low-tech improvements. And the fact that many GMO seeds must be purchased anew every year is another drawback. Partly this is because they are almost always hybrids. Hybrids are plants whose parents are different varieties of the same species. They are beloved by farmers because of what is known as hybrid vigor: the nearly magical ability for the plant to produce more edible food than either parent variety while also being harder to kill.

Unfortunately, the offspring of hybrids are duds, producing unpredictable crops. Scientists have been working on that too. Another UC Davis plant geneticist, Imtiyaz Khanday, stumbled on a way to tweak a single gene and make hybrids breed true. Khanday's hybrids create seeds that are clones of themselves—preserving all the benefits of hybrid vigor and whatever drought, flood, or pest tolerance the hybrids were engineered to express. He hasn't mastered the technique yet, but his breakthrough could theoretically work in all sorts of crops. Farmers could save seeds and replant. He hopes to see the first hybrid clones in farmers' fields in 10 years, but concedes, “I am being very optimistic about it.”

A carrot harvester stands in a field. PHOTOGRAPH: CODY COBB

ON MY DRIVE back to Oregon from Davis, I started imagining what agriculture could look like if it were optimized for climate. What if, instead of focusing on inputs like chemicals or genetically modified seeds, we threw out the old rules and started looking at outputs—like greenhouse gas emissions, land and water footprint, pollution, worker and consumer health and safety? The result might look like a mashup of organic and conventional, depending on the context and the crop. High yield, low emissions. And it might borrow heavily from a style of farming that's become a bit of a buzzword recently: regenerative agriculture.

The core concern in regenerative farming is storing more carbon in the soil. This has a double benefit: Carbon dioxide is pulled out of the atmosphere, and the stored carbon helps nourish the soil. Practically, this means that farmers try to keep the soil covered and undisturbed as much as possible. They reduce or eliminate tillage—plowing, harrowing, or otherwise churning up the soil. They use crops like clover to keep the ground covered and add nutrients when the

fields are fallow. They use composts and manures, plant perennial crops rather than annuals, and incorporate charred vegetation residue into the soil. All these practices can change the ecosystem of the soil and its physical properties, making it better at holding moisture, nutrients, and carbon.

The number of acres in the US that are farmed without tilling increased from 96 million to 104 million between 2012 and 2017. During that same time, the amount of land planted with cover crops jumped from 10.2 million acres to 15.3 million acres. But consider this: There are 899 million acres of farmed land in the US. Farmers are a pragmatic bunch. If they are going to make changes, it has to pay. Back at home, I scheduled an interview with a startup called Indigo Ag, which has one nascent effort in that direction.

Raoul Adamchak rides a bike at a University of California, Davis student farm. PHOTOGRAPH: CODY COBB

Based in Boston, with about $850 million in investment capital, Indigo pays farmers around $15 for every ton of carbon they add to their soil. Indigo claims that if every farmer boosted the proportion of their soil that is carbon to 3 percent (today's average is 1 percent), they could together draw down 1 trillion tons of CO2—"the amount of carbon dioxide that has accumulated in the atmosphere since the beginning of the industrial revolution"—a figure that some soil experts say might be a bit aspirational.

Indigo also tries to connect farmers with buyers who appreciate more environmentally friendly practices. Corn, soy, rice, and cotton are typically sold as commodity crops at a standard price. Indigo Ag, however, runs a specialty marketplace where growers of crops who use sustainable practices—or grow grain to particular specifications—can sell their wares directly to food companies. "We think it is inevitable that our food system shifts to being decommoditized so farmers get paid not based on inputs or principles"—as in today's organic farming—"but on commitments to nutritional quality and environmental protection," says Geoffrey von Maltzahn, Indigo Ag's chief innovation officer. Anheuser-Busch is buying 2.2 million bushels of rice through Indigo, specifying that the grain must be made with 10 percent

less water, 10 percent less nitrogen, and produce 10 percent less emissions than generic commodity rice—producing a Bud you can presumably quaff with 10 percent less guilt.

Getting enough farmers to store carbon will require more than a few virtue-signaling companies to pay a premium for their crops. Bigger forces have to come to bear. Indigo hopes governments will eventually incentivize farmers to store carbon—ideally setting a global price for every ton they are able to sock away, which von Maltzahn says would be "transformative to the economics of developing- and developed-world farmers."

Some policies already exist to encourage better agricultural practices. The US spends about $6 billion each year on programs that compensate farmers for environmental services like conserving topsoil or wildlife habitat. States run their own programs too. At Terranova, Don Cameron is tapping into one of these state programs to help pay for a 1.5-mile corridor of plants that support pollinators and insects that eat crop pests.

One can imagine a future where “farmers” spend just as much time and make as much money storing carbon and maintaining clean water and wildlife as they do selling soybeans and carrots. Farmers in such a system could become a real climate-mitigation force. Consumers would have a slew of new labels to choose from beyond organic: regenerative, carbon negative, wildlife friendly, and so on. In the best of all possible futures, one can imagine that these approaches become so mainstream that the labels simply disappear, because incentives and regulations ensure that all agriculture is producing safe, healthy food while simultaneously improving the environment.

In a system judged by outputs, not inputs, farmers could mix gene editing and automation with cover crops and compost and monarch butterflies and owls. They could create their own kind of hybrid vigor.

Planning the future of the food system made me hungry. When I got home, I chopped up some conventional orange carrots that Cameron had yanked out of the ground for me at Terranova and some of Adamchak's organic purple and white carrots and mixed them together. I drizzled them in olive oil from California groves, seasoned them with salt and pepper, and roasted them in the oven. My kids couldn't get enough.

EMMA MARRIS *(@emma_marris) writes about the environment and wild things.*

This article appears in the April issue. Subscribe now.

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Nourish

The Climate Issue | How We'll Feed—and Save—the Planet

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Featured Video

How Food Is Different in Space

What's different about food in space? Former NASA astronaut Mike Massimino breaks down all the differences between eating on Earth and eating in space. Is astronaut ice cream REALLY a thing? Who decides what food is brought to space? Can you eat burgers in space? Why do astronauts use tortillas instead of bread? Mike Massimino is a former NASA astronaut, senior advisor for space programs at the Intrepid Museum, and professor at Columbia University.

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