Land Report

Number 120, *Spring* 2018 · *The Land Institute*

About The Land Institute

MISSION STATEMENT

When people, land and community are as one, all three members prosper; when they relate not as members but as competing interests, all three are exploited. By consulting nature as the source and measure of that membership, The Land Institute seeks to develop an agriculture that will save soil from being lost or poisoned, while promoting a community life at once prosperous and enduring.

OUR WORK

Thousands of new perennial grain plants live year-round at The Land Institute, prototypes we developed in pursuit of a new agriculture that mimics natural ecosystems. Grown in polycultures, perennial crops require less fertilizer, herbicide and pesticide. Their root systems are massive. They manage water better, exchange nutrients more efficiently and hold soil against the erosion of water and wind. This strengthens the plants' resilience to weather extremes, and restores the soil's capacity to hold carbon. Our aim is to make conservation a consequence, not a casualty, of agricultural production.

LAND REPORT

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Cover

Heads of select plants are bagged together for mating, with help from intern – and drummer – Carl Bowden, who taps with a bamboo stake to loosen pollen. This breeding is to put good crop traits from wheat into the perennial intermediate wheatgrass. For wheatgrass developments, in food and field, see pages 17 and 28. Scott Bontz photo.

Cosette Joyner Armstrong, in trying to make clothing production and consumption more sustainable, encourages people to develop their own styles. Declare independence from corporate direction, she says, to support small manufacturers, locally attuned supply chains, and recycled fabrics and benign fibers. "You know, how nature does it." Here Land Institute ecology technician James Bowden models, on restored prairie, his own T-shirt graphic, a comparison of the roots of a perennial grass and annual wheat. Scott Bontz photo.

The warp of the world

Clothes make the man and woman, but depend on Earth's exquisite coat

SCOTT BONTZ

Cosette Joyner Armstrong's glasses are a big, cat eye frame that sweeps to points beyond her small, round face. In her photo on Oklahoma State University's website, she wears kernels of silver earrings and a textured black blouse under a ruffled collar. By the picture is her title: associate professor of Design, Housing, and Merchandising. Her doctorate, from Kansas State, is in Human Ecology: Apparel and Textiles. In one word, the subject of her study and teaching, and her interest since long before, is fashion. This industry rolls up world sales well over $1 trillion, with more than $250 billion in the US. But look at Joyner Armstrong's professional approach to the field: she teaches a course called "Wicked Problems of Industrial Practice," and has written a paper titled "Toward Design Recipes to Curb the Clothing Carbohydrate Binge." For the industry and its consumers, she wants a radical makeover: how to look sharp ecologically.

Early last winter Joyner Armstrong visited The Land Institute. (In a polo shirt, plain but for embroidery at the left breast spelling "OSU," in the school colors, orange and black.) She came to plan an August return with her students. Institute researchers would explain how, in looking to remake agriculture, they've studied the land's natural economies. Fashion too could use this kind of inquiry.

"How much fashion do we need?" asked Alabama designer Natalie Chanin, who "upcycles" used fabric for couture, and whom Joyner Armstrong met while working on her master's degree. The question introduced her to thinking about sustainability in fashion, and it was exciting.

She had 15 years managing retail and designing display for Sears and Talbots clothing. And she still has lots of clothes. "I just recently let go of about 12 pairs of shoes!" she wrote in follow-up to an interview. "Now I'm challenging myself to own fewer, high quality boots and shoes, and wear them a lot. I own a lot of T-shirts and blouses because these provide a lot of versatility and variety. I can layer them in different ways and gain a sense of newness while owning only a small number of pants and skirts to pair them with." She's grown closer to a personal style, and developed a different feel for her apparel. "I use all of it," she said in the interview. "I rarely throw something out." It's a healthier relationship. To buy a piece of clothing, she said, "There's got to be a long-term plan. It's like a marriage. … That thing has got to fit in with everything else."

Joyner Armstrong wants students to recognize with their clothes this kind of personal responsibility. Impressing such understanding and ethic is harder with textbooks and classroom lecture than with direct view of nature's workings. "You've got to get

them outside," she said. She wants her students to learn how to look at a landscape, and to recognize what's missing; to distinguish the biotic and the abiotic; to engage nature, and to notice things they'd taken for granted. She wants them then to reflect on this, personally or for industry.

For one example from nature, she said, "Everything is local. Everything folds back into the system. There is no waste." How could clothing do this? Use sunlight instead of fossil fuels. Recycle spent fabric. And like birds' beaks evolving with seed size, adapt design to knowledge of the ecosphere.

Joyner Armstrong has taught biomimicry classes at Taos, New Mexico, which has landscapes from desert gorge to lush forest, and in Costa Rica, a small country with nearly 4 percent of the world's species. She thought, "How do I do this closer to home?" Nearly 70 percent of OSU students are from Oklahoma. And how can she give an agriculture experience outside the industrial paradigm? Hence her plans for a visit to Land Institute fields.

These fields remain human landscapes, but they are made with thought of nature's economics. And the institute has not just experimental crop fields, but also hundreds of acres of native and restored prairie, and woods, and even a hill spotted with yucca. Nature inspires ideas, Joyner Armstrong said.

Back to how much fashion we need. Do we need it at all? If keeping up with fashion is stressful, then fixed and fairly homogenous dress like that of the Amish can spell relief. But Joyner Armstrong says we need fashion for creative expression, for sense of identity. And we change.

To fulfill this need, however, she wants a new awareness and approach: "Match your consumption level with what the ecosystem can provide."

On how to do this, she is still at work. But for example, consider cotton, the biggest consumer of crop pesticides, and polyester, made from petroleum at more than double cotton's rate of energy use and carbon dioxide loss. Together these two fibers make 80 percent of our textiles, which a Forbes story in 2016 said accounts for 10 percent of greenhouse gas emissions. What about hemp and flax, she said, natural fibers now more costly, but which need less water and energy? (See the story on page 9.)

That is only about how clothing is made. Perhaps more important – and already within our control – is clothing's sheer quantity. Cheap energy has given us loads of cheap garb, and to put it in, big houses with walk-in closets. And it has cheapened our care of clothes. The Economist reported last April that in a decade and a half global clothing production doubled, and most kinds of clothes are now kept only half as long. The industry pushes volume by altering style prescriptions at more than double the rate of Earth's changing seasons. Most "fast fashion" items are chucked within a year, the magazine said.

We don't all play this spree. But the Council for Textile Recycling estimated that the average American sheds textiles – including upholstery, curtains, and bedding – at the rate of about 70 pounds per year. (Stockholm Environment Institute's ecological footprint study in Britain put clothing and footwear's share of textiles at about three-fourths. Apparel's footprint was a little more than half that of alcoholic drinks, and a little more than a third that of cars.)

About 12 pounds of that cast off fabric is donated or recycled, the Environmental Protection Agency said. But thrift stores reportedly resell only about a fifth of donated clothes. The textile council said about half of the donations are recycled as rags or fiber

for such things as insulation and carpet padding. The majority of what's left becomes hand-me-down exports, and the last 5 percent joins the 58 pounds per American that goes straight to the landfill – more than 10 million tons, 5 to 7 percent of the nation's buried waste. The EPA shows textiles as one of the least recycled materials: at 16 percent, about the same rate as wood.

Giving rather than trashing clothes can alleviate guilt, and to spare the landfill is good. But supply already far exceeds US demand for secondhand clothes, and Joyner Armstrong said the more volatile economies of poor countries suffer consequences from our castoffs. A crackdown on imports by Rwanda, Tanzania, and Uganda to promote home fashion industries has divided those nations' peoples and provoked a trade dispute with the US.

What would help with secondhand clothing is if instead of just giving it away, more of us bought and wore it. Joyner Armstrong thinks, and loves, that Americans decreasingly consider this beneath them. But the fraction remains small. She wants to make secondhand sexy.

Help might come from services like the slick online garage sale Poshmark. But there you don't see the word "secondhand." You find a "social commerce marketplace for fashion," and on the opening page, emphasis of brand names. Joyner Armstrong fears this kind of appeal might actually increase casting off and consumption, rather than promoting frugal consciousness of what clothing manufacture takes. "I'm skeptical of their sustainability," she said.

Instead of your strategy being to get for cheap the fashions driven by big industry, buy secondhand clothes to give yourself distinct style, she said. The aim shouldn't be finding a deal, it should be avoiding a new garment. Because every dress, shirt, and sock carries cost in soil erosion, water use, pesticides, energy, or pollution. Often it bears all of these things. The consultancy McKinsey calculated that making 1 pound of clothing releases 23 pounds of greenhouse gases.

Among research listed on Joyner Armstrong's OSU web page is "sustainable consumption." She studies how consumers may become emotionally attached to clothing, and what will bring them to buy less of it and to keep it longer. The people most engaged in fashion are young women. They use it to develop identity. If you are caught up in this, she said, you might have "nine different people hanging in your closet." She's interested in people whose esthetic identity is more settled. Her name for this is "style confidence," and it comes with two behaviors. One is "wardrobe engagement": you know well your closet's contents, and make thorough use it. The other is "wardrobe preservation": you give your clothes loving care.

There's much left to learn about psychology, clothing, and sustainability, Joyner Armstrong said. But she notes that we tend to steward better our suits and cocktail dresses, because they adorn us for memorable events. Dress clothing also tends to last because we don it less often, the quality is higher, and the styling tends to be more classic, less trendy. Though people she's studied have shown attachment to T-shirts many years old, everyday clothing get heavy use and demands quicker replacement.

So, especially if we wear it out fast, how should clothing be made? Joyner Armstrong cited British designer Stuart Walker in wanting for fashion a kind of humility. What he means might run counter to the idea of durability. But while designing a shirt we should include the end of its life. We might build it better, to last, but we

should also build it for easy disassembly or disintegration. The oldest form of recycling is that of textiles, Joyner Armstrong said. Can't we again make clothes that are recyclable, or disposable – something safe to bury in the garden?

The adventure clothier Patagonia promotes repair and recycling of its garments. But a fleece jacket is still made of plastic from petroleum. Many fabrics now are blends of natural fibers and the cheaper synthetics. Recycling this is tough. Separating the fibers mechanically degrades them, and chemical methods are expensive. And sending fleece, organic cotton, or wool to Patagonia's service center in Nevada takes more fossil fuel. For sustainable clothing, Joyner Armstrong said, make its manufacture small scale and local.

That's the aim of an organization called Fibershed. Seven years ago Rebecca Burgess made a personal project of assembling a wardrobe made with dyes, fiber, and labor no more than 150 miles from her home at San Geronimo, north of San Francisco. The project grew into a nonprofit that now has affiliate fibersheds across North America, and several in Europe and Australia. The aim is farming and clothing that builds soil and ecosphere health. Tests of soil carbon, and education in how to build it, are offered to growers of fiber and dye crops in the original fibershed in Northern California. Dozens of growers appear on Fibershed's Web site. Most of their fiber is from sheep and alpaca, with one flax project across the Central Valley in Chico. Nearer San Francisco are member clothing makers.

Joyner Armstrong also want to see clothing fit its time. Sustainable dress has suffered a reputation of "granola." She wants clothes that are both compostable and alluring. People like good design. And they give it more care. She cited another British designer, Vivienne Westwood, as saying something beautiful lasts longer in the wardrobe. And by appealing to their desire to dress well, people may be subtly seduced to live well. "We use this to pull people into a sustainable lifestyle," Joyner Armstrong said.

Included could be "upcycling" like Chanin's, cutting apart old clothes and sewing them into new fashions. But we still largely face a "prescriptive model" for homogenous dress, from an industry hanging on volume, scaled out of control, producing at a pace that allows only nips and tucks rather than creation of "clothes that are distinct and the true embodiment of fashion," she said. Outside of the runway, in the mall, "Store after store, you see the same thing." The culture of mass production wants us want to fit the clothes. "Young women buy into this homogeneity, even as they seek unique identities. Could we have a different kind of industry, that fosters self-expression?"

She sees dress beginning to become more diverse, with some people developing their own styles, and some retailers – Stitch Fix, Letote, Trunk Club – trying to respond. She hopes rising heterogeneity opens niches – that it supports small designers and manufacturers, smaller and more locally attuned supply chains, and more diverse materials, such as recycled fabrics and benign fibers. "You know, how nature does it."

This kind of change won't be driven by industry, she said, but only by consumers. And she said more consumers are pushing back against homogeneity. They want through their clothing to be part of a story. In their clothes they want to find meaning.

The soil and oil on our backs

Our clothing is much like our food, in that only a small fraction of it comes from the energy of contemporary sunlight via perennial plants, soil's natural conservators. Cotton, source of more than three-fourths of natural textile fiber, and grown as an annual, occupies 2.5 percent of cultivated ground. So the Land Institute has kept its development of herbaceous perennial crops to those that feed people.

But cotton uses more agricultural pesticides than any other crop. This, breeding, and irrigation have helped keep acreage devoted to it fairly steady over more than half a century, even while yields almost quadrupled. In the same time its share of the clothing on our backs is down from two-thirds in the 1960s to less than one-fourth now. Most textiles today are synthesized from petroleum. Polyester from cheap oil costs less than cotton's labors, takes less land surface, and, according to the Stockholm Environment Institute, uses one-thousandth of the water. But synthetics don't quickly break down and feed soil, as do natural fibers. And plastic, from bags and bottles to microscopic fibers, pollute our water.

How will we dress ourselves when oil becomes too costly to make polyester or pesticides? Growing more annual cotton would expose more land. Every year demands another planting, another beginning from the smallest point, a seed. Soil thus bared and churned by disc or plow is soil exposed to erosion and vented of carbon – carbon turned from soil-enriching compounds into climate-changing gases.

All four of the cotton species grown as crops originated in the tropics and subtropics, and all four were perennials. "By selection, we now grow the perennial scrubs as annuals in temperate regions," said Fred Bourland, who was raised on a cotton and soybean farm, and has been breeding cotton since 1970, now at the University of Arkansas. "The perennial nature is still in

Lewis flax, a perennial in the same genus as common flax, the annual used for flax seed, linseed oil, and linen, once a common textile. A former Land Institute fellow has begun testing Lewis flax as an oilseed crop. Might it also be bred for fiber? Scott Bontz photo.

the plant, but the plants are killed by our winter temperatures."

Tassawar Hussain Malik, director of agricultural research for Pakistan Central Cotton Committee, said perennial cotton is kept for experiments, but none is commercially grown in his nation, which is a top producer, along with India, China, and the US. Severe pest and disease threats rule out the possibility, he said in email, adding, "It took centuries of manmade evolution (breeding) to transform it from perennial to annual. Reverse is a long-term process as well, and with doubtful possibilities."

Bourland said south Texas and Arizona farmers once grew "stub cotton." After harvest, producers shredded the stalks and allowed plants to regrow the following year. This cut the cost of replanting. But shredding spread viruses, and latent greenery harbored insect pests including pink bollworm. The practice ended.

Viruses aren't a problem for US cotton farming now, Bourland said, but they remain so in the tropics. He thought perennial cotton probably could be developed for temperate zones, but in addition to pests and disease would come the problem of weeds. "The question is whether it's worth the trouble," he said.

Before Britain tapped cotton from India, and Southern slaves and Whitney's gin made cotton cheap and king in the early 1800s, most Europeans and North Americans had a choice of two clothing fibers, wool or linen. For 500 years the seat of the lord speaker in Britain's House of Lords has been the "woolsack," a reminder of the nation's chief wealth source in the Middle Ages. (Discovered in 1938 was that the stuffing had been changed to horse hair. As a symbol of unity, it was repacked with wool from across the Commonwealth.)

Wool's role now lies vastly reduced. Like silk, long a luxury, it is from animals –middlemen who, along with processing, raise the cost over cotton's. But these animals live on perennial vegetation. And an organic cotton shirt can approach the price of low-end wool.

Linen comes from stem fibers in flax, which also gives us flax seed, for both eating and making linseed oil. These confusing popular names are for a species among more than 200 in the genus *Linum*. The crop plant, common flax, is an annual, but some other flaxes in *Linum* are perennials.

Though it now costs more than cotton, two studies have found that linen takes far less energy to make than do other fabrics, natural or synthetic. (See first table below.) But cotton fiber comes off the top of the plant, and already dry, making harvest relatively easy, especially in the machine age. Flax, in a process called retting, a partial rot to expose fibers in the stem, must be neatly laid on damp ground or in water. This is partly why instead of cutting the stem aboveground, like with a grain crop, harvest traditionally has been to pull up the short-rooted plant. That's also easier than stooping or crawling with a sickle to cut an inch above the ground, below the first true leaves and tough stem fibers. But pulling would defeat the purpose of a perennial.

Alvin Ulrich, of Biolin Research in Saskatchewan, said harvest machines such as a sickle bar mower and a floating header can cut stems close to ground. Farmers already use floating headers for lentils and chickpeas, which may bear low-hanging seed pods. Ulrich has campaigned for prairie province farmers, the world leader in flax seed production, to stop treating their leftover stems as crop residue, and turn them into profitable stock for shirts and slacks – plus for insulation, plastic composites, and even fiberglass. The biggest flax fiber

producers are in Europe, where plants are pulled and laid thinly on the ground to encourage retting.

The wild perennial Lewis flax already looks more like its cultivated relative than did some of The Land Institute's startup species, said Brent Hulke, who as a graduate student at the University of Minnesota was an institute fellow and began working with perennial flax. Institute researcher David Van Tassel said that to develop a perennial for fiber might take far less time than for grain, which in a wild plant is small. The main source for paper fiber is trees, perennials that have gone through nothing like the transformation of humanity's grain crops.

Hulke now breeds sunflower for the USDA in Fargo, North Dakota. Last fall he began a side project to develop Lewis flax as an oilseed crop. With that same goal, his collaborators at Minnesota report success at crossing perennial flax species with one another, though not yet at crossing a perennial with the annual crop plant. Lewis's seed is smaller than the annual crop's, but already plentiful. The plant is relatively short-lived, typically lasting only three to four years, but Hulke hopes to find enduring outliers. He thinks flax's value will rise because the seed packs omega-3 fatty acids crucial to our health. In response to the crackdown on unhealthful transfats, omega-3s have been bred out of soy and other oilseed crops so the oil will last longer on the shelf and in fryers.

Ulrich didn't think any other flax matched the existing crop for fiber. But a Peterson's field guide said Lewis, named after explorer Meriwether Lewis, was similar: "If you question your identification of this plant, try twisting one of the stems. It should behave like a piece of string and not readily break. The long tough fibres in the stem are quite characteristic." Peterson's describes blue flowers on "stems so slender that they continually sway, even when there is no apparent breeze."

A third annual, hemp, takes far less water, land, and pest killer than cotton. But although lower in marijuana's psychoactive chemical, THC, it is often considered the same species, and in the United States it struggles as plant non grata.

Difficulty in manufacture makes expensive the perennial fiber crops ramie and piña – the latter scraped from pineapple leaves. Both are often blended with other fibers, ramie because of low elasticity and resilience. In the Philippines, a prime producer, piña traditionally goes to wedding attire. A US piña importer, Eccosar, markets on its Web page only bags and scarves.

Apocynum cannabinum, a perennial whose popular names include dogbane and Indian hemp, has been used by Indians for ceremonial capes, skirts, and head-dresses, as well as for twine, rope, baskets, and netting. The Land Institute's Aubrey Streit Krug has made dogbane twine. "It's a slow process that involves skill, but can result in some surprisingly silky strong fiber," she said. Because of this the species name looks much like that of hemp's genus, *Cannabis*, though the two plants aren't even in the same order. *Apocynum* means "poisonous to dogs," and the plant is also toxic to livestock and people. It attracts butterflies, but, spreading underground, is a tough invader that gouges crop yields.

Other perennials such as agave and coconut make such things as doormats and rope, but their fiber is too coarse for clothes.

It would be awhile before someone develops soil-conserving perennials to clothe us. How do our current textile sources compare ecologically? There's a lot to consider, and different methods get different results in the tables below.

New Zealand, prime land of wool, wondered if that fiber's production was as ecologically pristine as the national image of white sheep on green hills. The Ministry of Agriculture and Forestry's Sustainable Farming Fund, and the nation's merino wool industry, hired a "sustainable growth" consultancy called Agrilink to compare eight materials for megajoules of energy burned per kilogram of fiber spun. The findings:

Flax	10
Cotton	55
Wool	63
Rayon	100
Polypropylene	115
Polyester	125
Acrylic	175
Nylon	250

The clothing company Zady, in the Forbes story cited on page 6, also put flax/linen clearly on top, but found wool taking a little less energy than cotton, and acrylic taking more than nylon.

The aforementioned Stockholm institute considered fewer fiber types, leaving out wool and linen, but looked at more treatments of hemp and cotton, and calculated more results. Its study was for the World Wildlife Fund office in Cymru, Great Britain, and that nation's BioRegional Development, which was interested in hemp textiles. The results for energy used to make natural fibers were lower than in the New Zealand analysis:

Organic cotton, India	12
Organic hemp	15
Conventional cotton, US	26
Conventional hemp	33
Polyester, Europe	104
Polyester, US	127

The polyester figures here differed possibly because of efficiency gains between the two case studies drawn from. Both include the energy used in getting polyester's feedstock. With that subtracted, the numbers would be more than a third lower – but still much higher than for the natural fibers.

The table above does not show all of the scenarios considered between the high of US polyester and the low of Indian organic cotton. Between them is US organic cotton. Because of a better fuel mix than in India, that was lowest for kilograms of carbon dioxide produced per ton of fiber spun:

Organic cotton, US	2.4
Organic cotton, India	3.8
Organic hemp	3.9
Conventional hemp	4.1
Conventional cotton, US	5.9
Polyester, US	9.5

The 23 pounds for carbon dioxide cited on page 7 is for production of clothing, not of basic threads presented here. In going from spun fiber to assembled cloth, the comparison of fabrics is a draw.

Finally, the Stockholm institute combined these results and others to arrive at ecological footprints. The World Wildlife Fund calls this the area of land and water required to produce the goods and assimilate their wastes. Again, the lowest to the highest, and a handful between, now in hectares required per ton of fiber spun:

Organic hemp	1.5
Conventional hemp	1.6
Organic cotton, US	2.2
Polyester, US	2.2
Conventional cotton, US	2.9
Conventional cotton, India	3.6

Riding the biodiversity rollercoaster

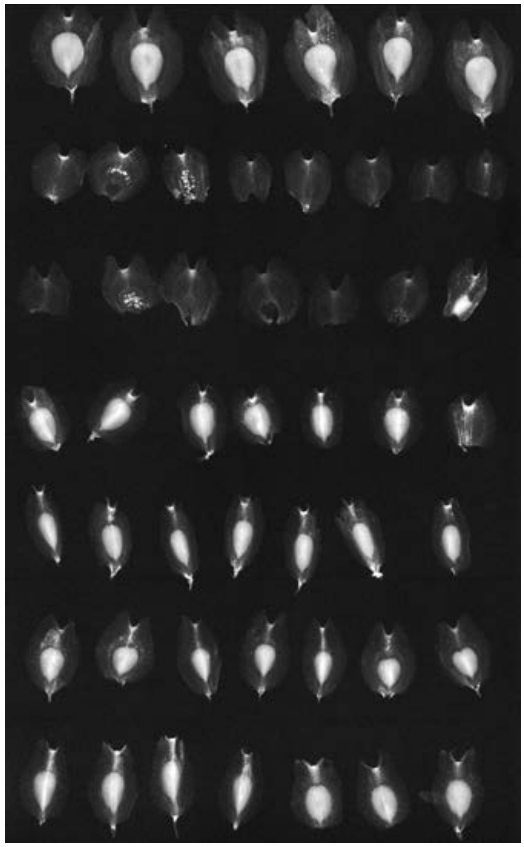
Grooming a plant that crawls with baggage

DAVID VAN TASSEL

About 15 years ago I became infatuated with the prairie plant *Silphium integrifolium* and invited it onto the farm to supplement our crop biodiversity in the spirit of someone adopting an adorable puppy to enrich their family. Silphium had large, tasty seeds, and seemed to ride out droughts in better shape than many other plants. Puppies also have many endearing features. But they may "enrich" your home with more biodiversity than you counted on: fleas, ticks, and parasitic worms. Silphium turned out to be a stray puppy-like biodiversity multiplier.

For about 10 years I was able to grow ever-larger plots of silphium with ease. Then came 2014. Our new research director, Tim Crews, was comparing dense monocultures of silphium with arrangements of mixed species. One of the densest, most lush plots turned rusty red in June, and by July the leaves were black with crusty silphium rust, a fungal disease. Our strong south summer winds blew spores north to a silphium breeding plot, and I watched as week-by-week the rust spread from the south and east edges, closest to Tim's plot. But infected late in the spring, these plants were not devastated like Tim's.

Until the next year. At that point, both of my large breeding plots were heavily infested, seriously weakening the plants. And a new problem surfaced in the younger plot: the growing points of most plants died in



X-ray of silphium fruits. Seeds show light through shadowy hulls. The second and third rows have been almost completely eaten, probably by fly maggots. Plants can't permanently trick all pests all the time, but silphium might be bred to fight back just enough that the damage is limited. The X-ray also shows how seed size and shape varies from plant to plant; each row represents a different mother. X-ray from Jim Campbell, USDA Agricultural Research Service.

the spring. The plants stopped growing taller, and later, recovering somewhat, sprouted new branches and leaves, so that by the time they finally flowered, the plants looked like misshapen bushes.

We suspected that lygus bugs had joined the silphium ecosystem. These insects inject something that helps them suck plant sap, but it also can kill growing points. I waited a year, hoping that the plants would recover and that the bugs and rust might skip us in 2016. But no such luck. This large plot had many lines promising to bring us our largest seeds ever. But I gave it up for lost. You can't find big seeds if the plants are weak and produce no heads! As in the past, I settled for cross-pollinating the few normal-looking plants with each other, regardless of their seed traits. But our luck was about to turn.

By 2017, we had learned to plant silphium in wider rows to improve air circulation and reduce opportunities for fungi. Even more encouraging: the descendants of rare, seemingly rust-immune plants that we had crossed in 2015 and 2016 showed a range of resistance to rust, from mild symptoms to complete immunity. Needless to say, plants with healthy leaves tend to grow much more vigorously. June is rust season in Kansas, and we were feeling pleased with ourselves.

Then the plants started to flower. We already knew that a moth had joined the party, infesting heads late in the season. On the advice of Jarrad Prasifka, USDA sunflower entomologist, my research assistant Kelsey Peterson began surveying random silphium heads each week last summer. To our horror, even many of the earliest heads contained a fat *Eucosma* moth caterpillar. And within a few weeks, close to 100 percent of heads were infested. By summer's end almost 100 percent of the stem bases also housed a *Eucosma* caterpillar. It turns out that after polishing off a silphium head, a caterpillar drops to the ground, gnaws into a silphium stem, and then tunnels into the rhizome, an underground stem, where it spends the winter. The tunneling severely weakens the stems, and many of them fall over in the wind.

So – biodiversity? Adding one plant, silphium, has, by now, added a silphium-specific fungus, attracted lygus bugs, and invited in a normally rare moth species that completes its entire lifecycle in or on silphium. But wait, there's more. Jarrad identified, and Kelsey began frequently seeing, a miniscule wasp that lays its eggs in silphium flowers, causing them to become deformed. Another parasitic wasp lays its eggs in the stems, forming tumors the size of goose eggs. A fly lays eggs where the developing maggots can each eat a silphium seed. Japanese beetles converge upon open wounds in silphium, and larvae spend the winter eating roots. And there are several species of weevils, stem-borers, and moths that normally attack sunflowers but do not scruple to feast upon silphium when the opportunity arrives.

If there is justice, each of these pest species will now attract five species that eat them. An entire food web should develop, restoring some balance, or at least predictability. At the base of the food web, however, will still be silphium. Total plant consumption is currently rather small, but devastation to seed production is large, and several of these pests cause damage that is very disproportionate to the amount of silphium biomass that they pull into that food web. One caterpillar can weaken an entire stem, causing dozens of seed-filled heads to fall to the ground, where they are beyond the reach of the harvester.

I refuse to give up without a fight. There's no hope of permanently tricking

pest species that are evolved to find and penetrate silphium. However, we may be able to breed silphium to fight back just enough that the damage is limited. What if the caterpillars are allowed to feast on the male flowers but find the female flowers – containing the seeds – sticky with bitter silphium resins? (After all, the plant's popular name is rosinweed.) What if a caterpillar can burrow into a stem but the stem is so hard and fibrous that the animal must make a small, straight burrow instead of hollowing out a cavern? We need to make these insects work hard for what they consume, grow slowly, and possibly fight each other over limited space. Indeed, many caterpillars are known to be enthusiastic cannibals. Kelsey suspects that the caterpillars eat not only each other, but the wasp larvae. I'm open to the idea of "paying the piper's due" if the piper is predictable and scares off other pipers.

We will be testing some of these ideas this year, and we will be mounting a large-scale effort to find plants that can take a hit without collapsing. There are promising signs. We are seeing a few plants that have straight, strong stems. And while some plants' heads are mush, others show signs of damage but have largely intact seeds. Kelsey examined hundreds of caterpillar-damaged heads this winter and discovered that seeds in larger heads are the most likely to escape intact. Fortunately, head size is something we believe can be increased by breeding. It's easy to measure and its something we would have wanted to do anyway, even in a world without moths.

We take courage from our early successes against rust fungus. In that case, even though there seem to be genes causing immunity, evolutionary theory tells us to focus our efforts instead on susceptible plants – those with fungus but mild symptoms. These plants are tolerating and limiting the fungus, not completely outwitting it. As with the silphium moth, silphium rust will not be outwitted for long.

It is possible that in the long-term, the silphium cropping system will become massively biodiverse, making it very difficult for any but the most specialized pests to explode. We may need to plant among the silphium other species, including hosts of spiders and insects that eat other insects. We may need to inoculate the soil with beneficial fungi, or simply wait for beneficial soil organisms to return.

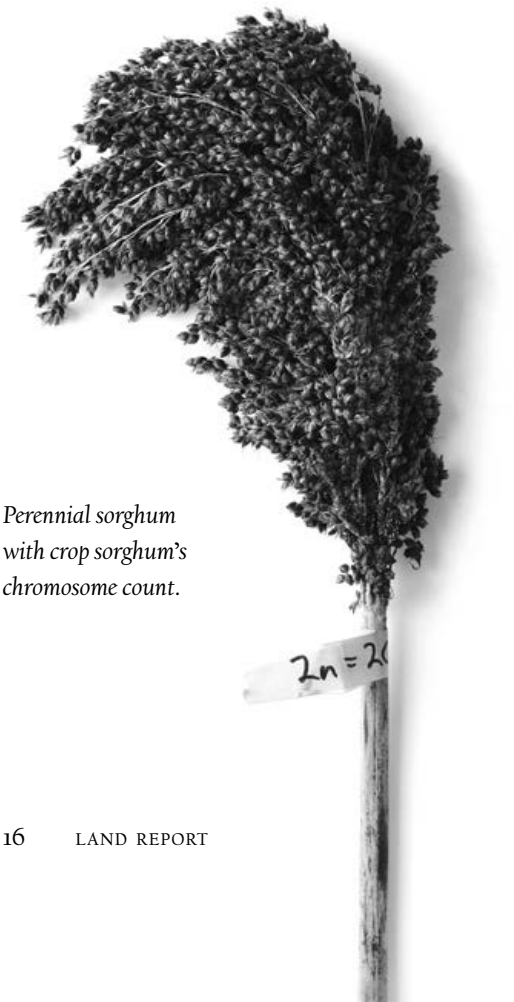
The other day I saw a beautiful goldfinch poking around in silphium heads. Ever the optimist, I hoped it was gobbling up caterpillars and other larvae. Sadly, I learned that goldfinches eat just one thing: seeds. Why are the seed-eaters the only birds to have discovered my plots? We have had trouble with bacteria, fungi, insects, and now birds. Deer and cattle love silphium. If the fish or reptiles turn on us I'll know that we are doomed.

Increasing farm biodiversity may be our duty and may eventually smooth out our ride, but for the moment, the biodiversity rollercoaster has us hanging upside down, screaming, wishing that we were back at the beginning of the ride with just one new, adorable pet plant.

Land Institute shorts

A leap for sorghum

Annual grain sorghum's 20-chromosome set is a simple pairing, called diploid, like that in humans and other animals. The perennial *Sorghum halepense*, johnsongrass, doubles the arrangement, a 40-chromosome tetraploid. For more than a decade, our crossing of the two species to get a perennial grain crop produced tetraploids. This posed problems. The annual crop plants available for use as parents were limited to a handful of old, chemically created tetraploids and specialized "male sterile" diploid lines that don't make pollen. Researchers Stan Cox and Pheonah Nabukalu couldn't draw from the full genetic variety of the world's sorghum cultivars. Also, the offspring often set seed poorly. Finally, how traits are passed along in tetraploidy is tangled. Getting a family to "breed true," with dependable results, instead of making mongrels, was going to take many more generations of breeding than with a diploid. But in 2014, three-fourths of 165 new hybrids looked much more like crop plants. So did their offspring. And genetic testing has finally confirmed that – for reasons not yet fully understood – these new hybrids were diploids. Cox and Nabukalu can cross these with any diploid crop sorghum, vastly expanding their genetic pool, and, they hope, speeding their progress toward a commercial perennial grain.



Perennial sorghum with crop sorghum's chromosome count.

Perennial rice moves to farms

Perennial rice developed in league with The Land Institute is spreading from a Chinese university to research plots on farms, and to pilot production, institute President Fred Iutzi and researcher David Van Tassel said after visiting last fall. Van Tassel has made several trips to Yunnan University over the past decade, and called this one the most exciting. Perennial rice now claims about as much land in China as does The Land Institute's intermediate wheatgrass in this country. And rice yields are far higher. The plant is already on par with annual rice – not just in yield, but also in taste, our scientists said – and tropical Yunnan allows two crops a year. Perennial rice had been grown only in lowlands. Now about 70 families have it in mountain terraces. "They're starting to get out to the poor people and more

stressful sites," Van Tassel said. In Yunnan with the Americans were Laotian officials, interested in the rice for cutting soil erosion and fertilizer use in their upland farms. China has been keener on how perennials can save labor in lowland paddies. The Laotians left with seed and plans for launching their own research trial.

Chips made with Kernza®

On Amazon and its own web site, a Bloomsburg, Pennsylvania, baker sells chips made with sprouts from a The Land Institute grain crop. Columbia County Bread and Granola presents four-ounce boxes of Kernza® "flat bread." Instead of a pliable pita – which the company also makes – these are crunchy, thin, one-inch squares. Kernza is The Land Institute's name for food products made from its intermediate wheatgrass, a perennial. Columbia also sells flour made from sprouted Kernza. About half the grain used in the Columbia chips is Kernza. The other half is spelt, closely related to common bread wheat. Columbia's founder and owner, Doug Michael, said in an interview that the smaller wheatgrass sprouts are helped through wet grinding by the larger spelt. Michael associated his recovery from Lyme disease with eating bread made with sprouted grain instead of straight-grind flour. All of Columbia's breads use sprouts. It also makes flax-based granola. When a seed sprouts to become a plant, its makeup changes, including a drop in starch. Michael said this disassembly makes for better digestion. He wanted Kernza in Columbia's products because it's "not just a food, but a soil replenisher." The grain came through Plovgh, a Wisconsin company that finds commercial growers and markets for wheatgrass. It was not from our fields, but from one of those pioneering farmers, likely in the upper Midwest. Columbia's Bakers Guild Cafe, two blocks away, has made – but does not ship – Kernza muffins and taco shells.

Columbia County Bread and Granola makes chips with sprouts from a The Land Institute grain crop.

Perennial buckwheat in China

Three Chinese plant breeders who are trying to develop buckwheat as a perennial grain crop visited in November, interested in collaborating with us. The group from Guizhou Normal University, in Guiyang, has helped develop and commercialize a tea made from the leaves of perennial buckwheat. Getting a perennial seed crop has been tougher. The hurdles include survival of cold winters, seeds popping from hulls before harvest, and seeds setting at different times, rather than together, as needed for harvest. But these are challenges that other breeders and plants have overcome. The Guizhou researchers are selecting plants from wild perennial

species in the buckwheat genus *Fagopyrum*, and also making hybrids by crossing perennials with annual crop buckwheat. *Fagus* is Latin for beech, which like buckwheat has a triangular seed. *Pyros* is Greek for wheat.

Though not a tree, nor a grass, as is wheat, and so technically not a cereal, buckwheat is used as such, in breadstuffs and noodles. The Guizhou scientists claim these benefits from buckwheat: more essential amino ac-

Soil shows

A story 7 feet deep and centuries in the making: The Natural Resources Conservation Service drove steel tubes into various soils at The Land Institute and extracted cores for the institute to display and interpret. At left in this core is the topsoil, darkened and enriched with organic carbon, and with crumbly structure that improves air and water space. This particular soil lies in the floodplain, and a skilled eye can identify when floods piled on the sediment. Soil science has a taxonomy that discerns over 23,000 "series," with 39 in Salina's home county. Four soil cores were preserved with glue and mounted on the entry wall at our research building. Spencer Barriball photo.

ids than are found in cereals; carbohydrates that are slowly digested, lowering blood sugar load, especially beneficial to diabetics; high fiber; and richness in flavonoids, for which are claimed several health benefits, though these are still under study. From The Land Institute, Wes Jackson visited the buckwheat project leader, Qing-Fu Chen, and saw perennial buckwheat fields when touring China in 2016. Research Director Tim Crews met him at a perennial-rice meeting in Kunming last June.

Scientists of insects, infections

To deal with disease and pests in its new crops, The Land Institute added two research positions. Ebony Murrell is lead scientist for a new crop protection ecology program. She studied the interplay of pest insects as a post-doc for Pennsylvania State University. Before that, her subjects included mosquito larvae in water-filled tree holes, tires, and buckets, and how things such as fertilizer and cover cropping affect organic row crop defense against insect pests. In the lab she builds housing and sometimes even cooks for the insects who in the field are our enemies. It's much easier to first test pest management strategies on a small scale. Outside work, she likes to train dogs, sing, and make science parodies of pop songs. (See YouTube for her sendup of Paula Abdul's "Straight Up.") Her biology doctorate is from Illinois State University in Normal, near her hometown of Assumption.

Murrell

Kathryn Turner was already here for a two-year, post-doctoral assignment to decipher perennial wheat genetics. Now she has the long-term job of studying the diseases caused by fungi and other pathogens in all of our crops. "I spend quite a bit of time trying to make plants sick or even kill them," she says in a profile on our Web site. "'If any plants survive or withstand the infection, I will look for the genetic mechanisms used to resist the attack." Her doctoral work at University of Minnesota was on the wheat fungal disease called rust. This followed her 2005 Land Institute internship while an undergraduate in biology and environmental studies at Austin College, in Texas. She grew up in Oklahoma City. She enjoys canoeing, growing vegetables in a community garden, and hobbies with useful ends, including ceramics, quilting, and crochet.

Turner

New wheat technician

Piyush Labhsetwar is perennial wheat researcher Shuwen Wang's new technician. Labhsetwar earned his doctorate in biophysics and computational biology at the University of Illinois at Urbana-Champaign. Before, he studied at the Indian Institute of Technology in Madras, followed by internships in India, Austria, and France. During childhood in

Labhsetwar

Indore, India, his family would buy a quintal of wheat for the whole year, and clean it of chaff and stones using a sieve. "After many years and halfway across the world, I found myself doing the same thing at TLI," he says in a biographical sketch on our Web site. "Life has come full circle." His passion outside work is social justice.

His predecessor here, Jamie Bugel, is pursuing master's degree in agroecology at the University of Wisconsin. Applying what she learned here, Bugel helps develop "culinary" sweet corn – something less sugary than modern varieties, but that doesn't quickly go starchy like heirlooms. The market is small organic growers and chefs.

New administration staff

Anita Chase is executive assistant to President Fred Iutzi, and helps with communications including our Web site. For 12 years she assisted chief operating officers and vice deans, and worked in communications, at Northwestern University in Chicago. She wanted to be closer to where she grew up, Wichita, Kansas. She'd moved to Chicago to play music, and was guitarist, vocalist, and songwriter with the all-girl hard rock band ½ Mad Poet, and later joined The Lost Brigade (available on CAUDog Records). This after earning from Wichita State a music degree, with a minor in cultural anthropology.

Chase

Bryan Thompson edits, fact checks, and arranges meetings and travel for President Emeritus Wes Jackson, who is helping develop The Land Institute's ecosphere studies program. For two decades Thompson was a do-it-all news director for Kansas commercial radios stations, and for another 15 years he reported on health for Kansas Public Radio. His wife, Cindy Thompson, works in our greenhouse, and has developed recipes for Kernza®, our name for food made with grain from our intermediate wheatgrass. Bryan is her taste-tester, and enjoys it.

Thompson

Will Schneider is operations associate to chief operating officer Rachel Stroer, working on communications, fundraising research, social media, finance, and accounting. He was born and raised in the suburbs of Chicago, but is just one generation removed from a central Kansas farming family, and came to Kansas State University to study finance and economics. After earning his degree, last year he made the ancient pilgrimage of Camino de Santiago, backpacking 600 miles across northern Spain.

Schneider

Amanda Stirn's duties as a development associate include stewarding our visitors and contributors, and communications. "We have such a great constituency," she said, "and I enjoy hearing about everyone's backgrounds, as well as their unique ties with The Land." She grew up in

Stirn

Salina and earned a bachelor's degree in visual arts and psychology from Kansas Wesleyan University. Before joining us, she worked for a local-food hub in Los Angeles, for Youth Services at the Salina Public Library, and for several small local farms. She serves on the board of the local-food co-op.

Scott Allegrucci, for two years our senior manager of development and communications, resigned to manage the campaign of Brian McClendon, Democratic candidate for Kansas secretary of state.

Ecosphere studies has director

Aubrey Streit Krug joined us last year as a post-doctoral fellow in ecosphere studies. Beginning April 1, she will be the program's director, leading work to change how people think about the world and their place in it. That is, not as a bunch of living and non-living parts, and with people and environment divided, but as an intricate system to which we and all life continually owe our existence. This can change one's very sense of identity, and ethics. Streit Krug grew up in nearby Tipton, Kansas, where her parents farm. While an undergraduate she served as a Land Institute intern, and last year she finished her doctorate in English and Great Plains studies at the University of Nebraska. June 21-23, she and colleagues will present a course in ecosphere studies for the Summer Teacher Institute at Western State Colorado University, in Gunnison. If you're interested in attending, see www.western.edu/academics/extended-studies/summer-teacher-institute-2018.

Streit Krug

Board changes

Donald Worster, retired from Land Institute board service after 29 years, was promptly honored with the title of director emeritus. He will no longer vote, but can attend board meetings. Worster is also a professor emeritus, of the University of Kansas. He pioneered the field of environmental history, and wrote books including biographies of John Muir and John Wesley Powell, the recent "Shrinking the Earth: The Rise & Decline of Natural Abundance," and "Dust Bowl." The last work is how Wes Jackson, Land Institute president at the time, discovered Worster, and, by dropping him a card of appreciation, became his friend and colleague. In an interview from his new home in Corvallis, Oregon, Worster said The Land Institute, Jackson, and even the photos by fellow board member Terry Evans helped him redefine how history should be asking ecological questions, and how people are to feed themselves. "It's really been an extraordinary part of my life," he said. "I feel a deep personal gratitude." Worster retired

Worster

from KU in 2011, but was quickly picked up by Renmin University of China, in Beijing, where he is a "distinguished foreign expert," and helping make an international center for ecological history. He is also a professor of history, trying to shift thinking beyond national focus, to "planetary history." He teaches just half of a graduate seminar, but spends five months a year in China, a place he loves, both for how he is treated, and for what he witnesses as a historian. "I feel like I'm getting a front-row seat of amazing change."

The board added two members, Julia Olmstead and Ricardo Salvador. Olmstead is a program officer for the Minneapolis-based McKnight Foundation. While earning her master's degree in plant breeding and sustainable agriculture for Iowa State University, she was a Land Institute fellow. She earned another master's degree, from the University of California, Berkeley, in journalism, where her adviser was Michael Pollan, author of "The Omnivore's Dilemma" and several other popular books about food and farming. Before joining McKnight, she worked for the Institute for Agriculture and Trade Policy in Minneapolis, and the Farmer-Led Watershed Council Project at the University of Wisconsin-Extension.

Olmstead

Salvador directs the Food & Environment Program for the Union of Concerned Scientists. The Cambridge, Massachusetts, organization describes his job as working with "citizens, scientists, economists, and politicians" to make food more healthful, and to produce it more sustainably and equitably. He had a similar goal as program officer for the W. K. Kellogg Foundation. Before that, he taught the first course in sustainable agriculture at a land-grant university, Iowa State, where he earned a doctorate in crop production and physiology. He also helped establish the school's student-run organic farm.

Salvador

Chinese researcher visits

Yuying Shen, a grassland ecologist from Lanzhou University in China, for three months studied our approach to making grain crops more sustainable. Much of China's grasslands are overgrazed and severely degraded. Shen sees her work as similar to those of Tim Crews, our ecologist and research director. She studies pasture agronomy – how farming affects nutrient cycling, water use, and yields – and teaches grassland management. Lanzhou is in Gansu Province, bordering Mongolia in northwest China. It is high plateau country, and, far inland like Kansas, sees a wide seasonal temperature range. Crops include wheat, maize, millet, and cotton. Shen and other researchers want to make Chinese agriculture work better as integrated whole.

Shen

Press and presentations

The Land Institute helped stick-figure video producer MinuteEarth make a three-minute YouTube explanation of the 10,000-year-old problem of agriculture, and of solutions modeled after natural systems, including development of perennial grains and growing them in species mixtures. MinuteEarth, with more than 135 shorts, claims 1.79 million subscribers. "Why Farming is Broken," released last fall, has had more than half a million views. The winter issue of In Good Tilth, magazine of Oregon Tilth, features a 12-page photo essay about our perennial crops, focusing on intermediate wheatgrass. In the March issue of The Atlantic magazine, Charles C. Mann, in writing of how those trying to feed the growing human world split into camps of technologists and ecologists, touches on our work to develop perennial grains. Land Institute staff members made presentations in Colorado, Illinois, California, North Dakota, South Carolina, and Ontario, and by teleconference gave a guest lecture for Cornell University in New York. Scheduled presentations include April 18 in Ames, Iowa, May 5 in Craftsbury Common, Vermont, and August 9-10 in Richmond, British Columbia.

Spencer Barriball tends a population of alborea, the hybrid of alfalfa and a related species. Alborea is under evaluation for making a legume food seed crop that is perennial. The plants pictured are in the high tunnel, a sort of halfway greenhouse, after living in a room with bumblebees, which did the job of pollination. Scott Bontz photo.

Land Institute intern Nadine Dyskant-Miller wouldn't confine her college work to music composition, and took on ecology minded farming. "I need variety," she said. "My brain doesn't work that way." Scott Bontz photo.

Hired hands of The Land

SCOTT BONTZ

Creation of perennial grains takes much hands-on work in field, lab, and threshing room, and The Land Institute couldn't do it without a great deal of help from interns. They're usually undergraduates or recent grads, usually in life sciences. But last year brought a composer, and this year the return of a retired copy editor from Time. (See her poetry on page 27.) Along with our regular staff, their numbers are growing, up from three or so in the summers of a decade ago, to a dozen in the past year, and now including "winterns." Here begins a series of sketches of people who do crucial but often menial work in good cheer, eyes on the prize.

In Hinsdale, New York, flutist Nadine Dyskant-Miller took a high school music theory class, and the teacher turned her on to composition. "I like the feeling of making things," she said. "Writing music felt really good." So she studied composition at the University of Michigan.

There, a composition teacher turned her on to ecology. Music study didn't allow time for the second major she wanted, biology. But she took a second pursuit, ecology minded farming. Music could not be the all. "I need variety," she said. "My brain doesn't work that way."

In both works she seeks a likeness. She wants to play music for people "where they are, of their place" – a value of agrarianism. For either field, she said, "I often use the same words." For example: "place-oriented." And in each she seeks the personal scale: to know the people she serves.

She enthuses on her interests with someone she has only just met.

Hinsdale is 80 miles from Buffalo. The population is about 2,000. She called it rural, not really a town. Her first experience with farming came when her family bought food from local growers through subscription – community supported agriculture. She was about 12 when she volunteered for a CSA farmer to thin beets. Her novice's terror was uprooting too many. But she didn't.

The influential university composition teacher was Evan Chambers. His page on the Michigan Web site calls him a vocalist and Irish-traditional fiddler who puts folk music energy into contemporary classical idioms. His parents were 1950s folk revivalists. He talks about this influence for a 2012 interview in New Music Box. Under the headline "You Must Change Your Life," he also says, "It seems clear that at present we are at a very serious environmental, social, and economic crisis point, and for me it all boils down to a crisis of compassion. … Folk music from our own culture has the potential to remind us about who we are and what truly matters in part because it can bypass our defenses with its familiarity and get straight into our bodies." Dyskant-Miller took in that philosophy.

Her taste is broad and she hesitates to define genres, but the listening repertoire includes many folk singer-songwriters. She

> "It makes for a very long process, but it's worth it in the end."
>
> *Nadine Dyskant-Miller*

and her mother, on piano, have played for contra dances, a folk idiom. This year they'll release an album of traditional folk music. Her compositions include one for orchestra, but have been more for chamber music, including flute and piano, double bass and voice, and a trombone quartet. She also writes accompanying text, and fashioned a libretto – "more poetic than dialogue" – for a one-act opera to be performed this spring in Ann Arbor.

After graduating in 2015, she worked for half a year in Ann Arbor's Argus Farm Stop, where about 100 local growers sell on consignment. The university town also supports at Argus a cafe, yoga, poetry, and music jam sessions. There she witnessed farmers and eaters seeing each others' faces to make the localness of food vividly meaningful.

In summer 2016 she volunteered at organic farms in Quebec and Wisconsin. That winter she read John Steinbeck novels, and books about food, social justice, and sustainable agriculture, including Land Institute founder Wes Jackson's "Becoming Native to This Place." She likes poet Gary Snyder, novelist and essayist Barbara Kingsolver, and Robin Wall Kimmerer's combination of science and Native American tradition, "Braiding Sweetgrass." In spring she was at a Vermont farm to learn more, and to teach children. In late summer 2017 she arrived at The Land Institute.

The work here for seasonal interns involves much hoeing, threshing, and repetitive measurement. She knew this was coming, and didn't mind. Farming can be much like this, she said, and for her, physical work is meaningful work.

Her formerly vague ideas about plant breeding have been made hands-on and concrete. She now sees and understands spikelet formation on grain plant heads, seed shattering, and selection for changing a wild perennial into a perennial crop. She helped assemble a chamber to simulate winter and trigger plants to make seed. She measured how intermediate wheatgrass grew aboveground and below, and said, "Having contact with the actual root system – eight weeks and already a foot long – was absolutely incredible."

Her next stop is Chicago. She'll find a second job – maybe teaching gardening, maybe serving a cafe. But the making-things purpose of the move is return to an arrangement with three friends from college. They live together and work together, on music, theater, and writing. They decide matters only on consensus. She said, "It makes for a very long process, but it's worth it in the end."

Staking the Kernza

JEANNINE LAVERTY

In country school
we had inspection
every day.
Nails, teeth, hair, ears.
I wish I could see those charts
on the wall over by the piano.
The first place I learned what a grid is,
What it can do to a human.

I always felt sorry for the Murphy kids.
They didn't seem to get that
You could change
Didn't have to have those Xs.
I didn't think that maybe they lived without
Toothbrushes, nail files, shampoo.
Now, I know they lived without much.
My mom called them the Murphy tribe.

We lined up and got checked
But there was no cleaning, teaching,
handing out samples
Just shaming, staring, and silence.

The offspring on the bench
In front of me
Are so green
Potted up with labels
Watched over
Cared for.
Thrips are searched out and squelched.

Tenderly
We gather their locks,
Like the weekend father
In the coffee shop
Shaping his daughter's fine strands
Into a ponytail.

We serve these planned plants
Provide direction
Twist tieing the gathered leaves to the
bamboo supports,
Showing the space to grow
Through,
Guiding progress
Without touching or holding on,
Offering a kind of freedom.

The stems shoot up toward the greenhouse's
pseudo suns
And to the great big one outside
Shrouded in fog this fateful morning.

Can I undo those
Greencastle School mornings,
Remembering the Murphys in these
Small circles of airy learning?
Holding them
In these small circles
Of Light.

Jeannine Laverty is a storyteller who grew up on an Iowa farm and now lives in Saratoga Springs, New York. She has served as a Time copy editor, farm worker, and plant breeding assistant in The Land Institute greenhouse. Kernza is a registered trademark for products from our perennial grain called intermediate wheatgrass.

John Goertzen pours milled Kernza® from The Land Institute into a vessel called the mash tun, to make a beer called Crankcase. Kernza is the name for food from our intermediate wheatgrass, a perennial grain. Crankcase is a name inspired by a hotrod event in Salina, and made by Blue Skye Brewery & Eats. Goertzen is their head brewer. Kernza's share of grain in his 220-gallon recipe is 8 percent. This was simply based on the 50-pound bag we gave him. The rest of the grain, as usual in beer, is malted barley. Goertzen hopes this summer to make a beer that triples the Kernza. He said it gives Crankcase an orangey taste, and that wheat beer is more lemony. Here Kernza works with a citrusy hops variety called Mandarina Bavaria. Crankcase is from the hops-heavy family of beers called India pale ale. So is Long Root Ale, the first commercial beer to use Kernza. Long Root comes from Patagonia Provisions, which now also will use the first commercial field to grow wheatgrass with another species, alfalfa, for ecological gains. At 151 degrees Fahrenheit, the Crankcase mash looks and smells like hot porridge. The mash pulls sugars from the grains into water. Later comes the bittering addition of hops – the flower of a perennial – and then yeast to convert the sugars to alcohol. Crankcase is 7 percent alcohol. Scott Bontz photo.

First production field of two species

The grain crop intermediate wheatgrass grows with nitrogen-fixing alfalfa

SCOTT BONTZ

A year after the first large-scale product used perennial grain from The Land Institute – a beer initially sold in northern and central California – we sowed our first commercial field putting this plant and another species shoulder to shoulder, for gains of diversity and in-house, natural fertilizer.

The grain crop is intermediate wheatgrass, and the companion is alfalfa – plus symbiotic bacteria in the roots – to fix nitrogen. Our commercial partner is again Patagonia Provisions, a food branch of the California adventure clothier Patagonia.

Patagonia began selling Long Root Ale in October 2016. Kernza®, The Land Institute's name for food products made from its wheatgrass, constitutes 15 percent of the grain used in the barley-based ale.

In November, at the Perennial Agriculture Project Field Station just west of Lawrence and the University of Kansas, we seeded more than 16 acres of wheatgrass and alfalfa, alternating in rows a foot apart. Two more fields under the supervision of Valentin Picasso, a former Land Institute graduate fellow now at the University of Wisconsin, brings the bicultural planting to over 30 acres.

This is small scale compared with a typical field of grain. But from our mixed-species study plots of 20-by-20 feet, it is a leap.

Patagonia, along with Rodale Institute, the soap maker Dr. Bronner's, and others, is pushing for an agricultural certification beyond organic. The name for the new standard is "regenerative." This means taking soil health back toward the level enjoyed before agriculture, Land Institute Research Director Tim Crews said.

Farming's heart is grain crops, and until now grains have been annuals, whose yearly tillage mines and squanders the organic matter that makes good soil, and loses soil itself to erosion. Perennial crops hold the potential to generate soil. Organic matter's heart is carbon, and soil regeneration will reclaim carbon from the atmosphere. This could be a significant part of changes to check the rise of greenhouse gases.

Patagonia is now buying grain from more than 200 acres in intermediate wheatgrass, said Birgit Cameron, the company's senior director. It has expanded Long Root sales from California, to Oregon, Washington, and Japan, with plans for more growth, more beers, and "additional shelf stable products."

At the new biculture, our collaborators from the University of Kansas installed equipment that measures carbon gains and losses from the soil. Over the coming years this metering will tell a story valuable for establishing and managing perennial grains.

In this case the new agriculture replaced not annual cropping, but perennial prairie grasses and forbs. It was not a native

Gains by wheatgrass alone

The kind of instruments measuring carbon, energy, and water dynamics at our new field of intermediate wheatgrass and alfalfa near Lawrence, Kansas, have done the same kind of accounting since 2012 at a seven-acre stand of straight wheatgrass just downhill from our office near Salina. This replaced annual wheat in 2009. A technical report of data from four years appears online in Volume 249 of the journal Agricultural and Forest Meteorology. Here are key points:

- Wheatgrass reflected less radiation than do row crops such as maize and soybeans. This implies that it absorbs more energy for photosynthesis.
- Over four years, wheatgrass kept about 50 percent more carbon than the plants and soil life gave off in respiration – it took climate-warming carbon dioxide from the atmosphere and enriched the soil. The gains will shrink as soil fills with perennially spreading roots and their healthful rot, until reaching a carbon equilibrium near that of old native prairie or forest. Having started with a field depleted by annual cropping, attaining that balance will take decades.
- Not counting carbon taken in harvest, the wheatgrass field added more than 5 metric tons of carbon per hectare in each of the first two years, about 2.7 tons in the third year, and 1.2 tons in the fourth – the decline likely because of developments described above, plus use of less nitrogen fertilizer. Studies of annual soybean and maize found at best a gain of 0.9 ton, but usually carbon loss, from 0.8 to 3.2 tons.

The air-sniffing "eddy covariance" instruments used for the study are run by Nathaniel Brunsell's lab at the University of Kansas, which also monitors the dynamics of forests, farms, and cities.

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field, but a 10-year-old restoration effort, Crews said. The site was deemed best for the carbon gauging, as well as for grazing.

Plowing in the old plants made a feast of oxygen and accumulated organic matter for soil microbes, doubling exhalation of carbon dioxide to the atmosphere. A previous study, at the University of Michigan, found that tilling under perennial brome, an Old World grass used for pasture and hay, sacrificed seven years of carbon accrual. (But that might've been subsidized by brome's needs for fertilizer, which prairie plants can do without.) Such losses, now abetted by tractor engines and nitrogen manufacture, make farming a big part of climate change.

Along with making grain for Patagonia Provisions, this field and its monitors should give the first production-scale numbers for how perennial grains growing in mixtures move carbon between atmosphere and lithosphere.

Crews hopes by summer to see the new perennials photosynthesizing and packing away carbon faster than losses to the atmosphere. Early carbon building will be of plants, not of soil organic matter. The latter will rise after plants mature and begin shedding as much tissue as they build each growing season.

By that time we'll be testing how to keep wheatgrass and alfalfa in balance. Each

species can fill a niche and together make the most of soil. Alternating rows of quite different species can also set hurdles for pests and disease. But one species, especially the taller grass, can overwhelm the other. How can we check counterproductive competition without resort to chiseling plants and soil, which will send carbon back to the atmosphere? And without herbicides, which, in addition to possibly damaging more life than the weeds they target, are made by outpourings of fossil carbon? The challenge is great, and of great importance if perennial grains are to do as much as is hoped in putting Earth's carbon balance right.

From this pioneering field we should learn more than how to grow species mixtures while conserving carbon. Perennial doesn't mean immortal, however, and for disease control, or for shifts in climate or market, farmers will still need or want to rotate crops. How could they replace one perennial species with another in the mix, or remodel the whole field, and not take one carbon step back for the new agriculture's two steps forward?

We'll also see how the perennial grain crop can produce on a commercial scale while getting nitrogen only from the companion legume, alfalfa. No synthesized fertilizer, like most farmers use to subsidize their weakened soil, and no "Dumpster diving," as Crews calls how many organic farmers import manure from industrial livestock operations.

The new field might produce grain as soon as this summer. We might mow and let both crops dry in the field before gathering them with a combine. The two plants' seeds are quite different and should easily sift apart. Alfalfa, queen of the forages, is still only forage, but also one of the legumes that we're studying to make a producer of grain.

Collaborators in other states are already testing wheatgrass as a dual-purpose crop. Crews plans to put cattle on the new field and evaluate it for forage starting this fall.

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Kura clover, a legume being evaluated at The Land Institute as companion crop to perennial grains, last year made many clusters of four and even five leaves. Stress such as heat or drought can suppress the gene that says, "Make only three leaflets." Looks like Kansas might be the place to find lucky clovers. Spencer Barriball photo.