Land Report

Number 122, Fall 2018 · The Land Institute

About The Land Institute

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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

Sheila Cox prepares to break the dormancy of sorghum seed so it can be grown over winter in a greenhouse. Each packet holds the seed from one plant. Cox picks six seeds from a plant and puts them in a pillbox compartment. Boxes soak briefly in a chlorine solution to break down protective coating on the seed and allow germination. These seeds are from cross-pollinating annual and perennial sorghum, and then 12 generations of inbreeding, with two generations of self-pollination per year. After a few more generations of self-pollination, this population will be shared with other sorghum researchers as a unique and valuable resource for genomic studies. Genetic mapping is much easier and more precise with populations that are highly homozygous — that is, inbred. Scott Bontz photo.

Liz Koziol samples soil to measure spores made by fungi growing among the roots of prairie plants. The two life forms work together, trading carbon from the plants for phosphorus and other soil nutrients from the fungi. Most of the world's plant species can benefit from this relationship, sometimes increasing their growth several times over what it would be without the fungi. Annual crops, with their soil and soil fungi regularly disturbed, have to get by with less. Koziol studies how fungi might help The Land Institute's perennial crops. Scott Bontz photo.

Cryptic mass of the underground

Plants made the world we see with the help of fungi we're just getting to know

SCOTT BONTZ

William Mackie, a walrus-mustached doctor from Elgin, Scotland, was also a keen amateur geologist. One day in 1912, geology mapping took him to a field near a village called Rhynie. Along the field was a wall of stacked stone, and in the wall Mackie found chert, an organic quartz of microscopic crystals. Around Rhynie this usually lies under a meter of soil. Curious, Mackie cut and ground the rock optically flat and paper thin. In it were plant stems preserved so clearly that he could see the structure of their cells, and tests showed that these fossils had formed 410 million years before, when plants were just beginning to spread across and green the land. The Rhynie chert also showed that even then, before plants developed true leaves, hooked into their roots there appeared a helpful life form called arbuscular mycorrhizal fungi. Ancient, beneficial, and weirdly difficult to know.

Fungi you know aboveground include mushrooms and mold. Mycorrhizal fungi live unnoticed among roots. Some are parasites, but usually they are symbionts, also known as mutualists: plants give them carbon and energy, and they give to plants soil phosphorus, other nutrients they have farmed, and maybe water. (Even before this arrangement developed, mineral-dissolving fungi struck a similar deal with photosynthesizing algae to leave estuary edges and break down land rock, as lichens. Which led to the beginning of soil.) These fungi also guard the plant against diseases and poisons. Some mycorrhizae ply their trade just next to roots, including those of many tree species. In 80 percent or more of plant families the mycorrhizae go farther, poking into the root cell walls with microscopic arbuscules, from the Latin word for a bush or small tree, because they branch. Their form and function can also be likened to alveoli, traders of carbon and oxygen in our lungs.

This binding partnership helped plants to colonize land, and formed how many of them work and live. A fungi primer in the fall issue of a newspaper called The Natural Farmer said that without mycorrhizae the world's forest ecosystems would collapse. (Without another kind of fungi, saprophytes – the decomposers – forests and grasslands alike would bury themselves.) Cited beneficiaries, at least in some conditions, include barley, corn, millet, rice, sunflower, wheat, and many garden vegetables. Fungi might figure in the success of perennial versions of grain, legume, and oilseed crops, and The Land Institute is interested.

But until recently soil fungi have conducted this enterprise largely unobserved. Their active cells, in filamental strings called hyphae, are at most a tenth the diameter of the average human hair. Scientists have called them "cryptic," hidden. This despite fungi of a prairie filling the soil with a mass

second only to that made by perennial roots, three times that of soil bacteria, and vastly greater than that of soil invertebrates, according to Vaclav Smil's book "Energies." Mike Miller, of Argonne National Laboratory, estimated that there are more than 100 meters of hyphae in one cubic centimeter of prairie soil. As late as the 1970s, taxonomists had recognized just six genera of arbuscular mycorrhizal fungi. Now they've named 34. Knowledge has piled rapidly with the ability to cheaply read DNA. But these fungi are so unlike plants and animals, sometimes with hundreds of different nuclei in one cell, that it's not clear where to draw the line between species. Dedicated to this field are only about a dozen scientists.

One of them is Liz Koziol. Her name is Polish, and she pronounces the "z" more like the "s" in "usual." Koziol lives in Lawrence, Kansas, and included in her studies is how mycorrhizae might help The Land Institute's perennial crops. She also has a one-woman business called MycoBloom, which grows fungi to inoculate soil for gardens, vegetable farms, and prairie restorations. Her starter fungi come from native prairie of the region served. She thinks this especially important for restoration. Her science journal papers show that late-successional plant species – those of prairies that are diverse and stable – grow better with mycorrhizal fungi than do early-successional plants. Early plants tend to fill in after soil disturbance, and can exclude late plants, curbing diversity. Inoculation with the right fungi helps the prairie reach late succession. Koziol found that late-successional plants such as *Allium*, the genus including onions, and *Liatris*, perennial species with the common name blazing star, perform far better with particular fungus species. She's a critic of commercial inoculants with generic "weedy" fungi that propagate quickly and can thrive in disturbance. "Yeah, I'm biased," said Koziol, whose laptop sports stickers for MycoBloom and I ♥ Soil. "But my bias is based on the effects of reality."

Koziol's heart is in restoration. For that – for getting something as close to rich, complex native prairie as she can, and not just a handful of dominant species lumped in bunches, as happens in many start-over pastures – mycorrhizae are the key. It's cryptic, not charismatic like prairie wildflowers. But she said, "It's hard not to love something that's a useful tool." There's much to learn in making that tool useful for success of an agriculture which looks to diverse prairie as inspiration. Though beneficial fungi have been in soil all along, only now are we getting to understand them. With comprehension, she said, "We can be better at fixing things we've broken."

Koziol

"Growing up, I didn't know what a prairie was," Koziol said. This despite gems – "Some of the best ones I've ever seen" – within 100 miles of home. That was Portage, Indiana, a far suburb of Chicago. Farmland in that part of the country was row cropped, without grazing land like in Kansas. Just to the east of Portage lay Gary, to the north, Indiana Dunes National Lakeshore. To one side of the dunes on Lake Michigan was a steel mill, to the other an oil refinery. Her parents suffered asthma, and she chronic bronchitis.

Her father was a steel mill electrician who eventually went independent. Her mother taught elementary school. For most of the week, home was just Koziol and her

parents, but on weekends it was "six kids and pancakes." She has one half-brother and three half-sisters, all older, and family life included one of the half-sister's half-sister. "It's complicated and there are a lot of weird lines on my family tree," she said. Vacations for eight were aimed at being "somewhere between cheap and free." The family boated on the great lake and the region's many little ones. She loved hunting mushrooms with her father. "It's the first thing you can do in spring, and that makes me happy."

Koziol attended public schools. She tested well in biology, and reading the picture of a flower's parts came easy. Human anatomy and edible wildflowers intrigued her. "Maybe it was because I was sick all of the time growing up in Portage," she said. She finally freed herself of the bronchitis in a move downstate to Bloomington, for study of biology at Indiana University. She wanted to learn traditional Chinese medicine, as a simpler alternative to costly Western treatment, but came to feel lacking in the right people skills. She worked with developmentally disabled children, but the pay was poor. So she became a part-time technician in the lab of IU researchers – and spouses – Jim Bever and Peggy Schultz. This turned fulltime, and Koziol added another lab job working with sunflower, while still helping disabled children. Thus she settled her student debt. And her relationship with Schultz and Bever became more than a job.

Much of the thinking about ecology and evolution has developed around animals. But plants and fungi are different from animals in how they get food, how their genomes work, and in how little they move. Schultz, Bever, and their students wanted to add to the big picture these "peculiarities." Koziol's bachelor's degree had told her nothing about mycorrhizal fungi. But with the lab she pursued a doctorate in how communities of prairie plants and mycorrhizae together build and change.

Prairie plants are mostly long-lived perennials, tolerant of drought and flooding, generally more productive than annuals, valuable for landscaping and grazing lands. The Land Institute's mission is to make perennials valuable as grains, the source of most calories for humans. Perennials are far better for keeping soil together against wind and rain, and, with time, for getting soil moisture and nutrients to work better for the plants. In one of Earth's greatest ecological tragedies, the vast majority of American prairie, from Indiana to the Rockies, was plowed to grow annual grains. Briefly these plants were more profitable. This came from cashing in on the soil capital built by perennials.

Now prairie restorations are a considerable business. Koziol said most restorations fail to match the quality of native community. Seed is thrown down without knowledgeably matching plants and fungi that together made the original tapestry. In such crude restoration, black-eyed Susans clump, while in native prairie remnants, they scatter as gold accents on the botanical riches. Koziol said an untrained eye can see the difference.

Why does this matter? "Research has found that diverse systems are better," she said. "They are more stable, more productive, and more resistant to invasion by weeds and non-natives, more resistant to pathogens – even to drought and environmental stress." In one square meter of remnant prairie she has found up to 27 plant species. In a one-species ghetto, pests and pathogens which specialize in eating that species can make easy advances from plant to plant. With diversity they face energy-sapping gaps. Former USDA mycologist

Michael P. Amaranthus said in The Natural Farmer that mycorrhizae also wrap roots with a germ barrier and excrete antibiotics.

Discovering diverse places has given Koziol more than data for science papers. "I was in awe," she said of seeing her first remnant, at Beaver Lake Prairie Chicken Refuge, south of Gary and near the Illinois border. Since then she's visited about 15 remnants, in Oklahoma, Kansas, Missouri, Illinois, and Indiana. East of the Mississippi, in the land of corn and soybeans, prairies are few and small, typically two to five acres, nothing on the scale of the Kansas Flint Hills. They are pockets in graveyards, strips along the railroad. But they enjoy more rain than Great Plains prairies, and are more diverse, packing forbs and legumes of spectacular wildflower display. Koziol's favorite is Loda Cemetery Prairie Nature Preserve, twelve acres in Iroquois County, east central Illinois, with more than 130 native plant species. In Bloomington she restored her backyard to about 500 square feet of prairie. She adopted 45 species, mostly "lab trash plants." "I didn't put any grasses in it," she said. This brought lots of bees. "It was beautiful. It's really fun to be in a prairie when the sun is going down and there are bees in all the flowers."

Koziol lived in Bloomington for 13 years. Two years ago the University of Kansas lured away Schultz and Bever. Koziol still had a year and a half to go on her doctorate, but last year she sold her house and moved west for a post-doctoral position with her mentors. Though she had spent a summer house-sitting for a sister in Seattle, this was her first real move away from home in Indiana. Lawrence is much like Bloomington, with about 80,000 people, but less of a college town. During summer in Bloomington she could ride her bicycle down the middle of the street. The average age was 27. Koziol, now 34, was ready for change. With less rain, the trees in Kansas were shorter, the mushrooms fewer. Still, she said, "I'm always looking down. I'm not one of those bird people."

A flattened plant root with arbuscular mycorrhizal fungi. What looks like a railroad in the center of the root is where the plant conducts water and dissolved nutrients between roots and leaves. The dark, thin strands to its right are hyphae, the nutrient-carrying body of the fungus. The dark, bubbly structures are the fungus's arbuscules, which stick into the root and exchange nutrients taken from the soil by the fungus for carbon from the plant. Liz Koziol photo.

Fewer mushrooms, but still the soil consistently bears – is borne by – arbuscular mychorrhizal fungi, whose web of hyphae not only feed and protect plants, but store soil moisture. To store their genomes over winter the hyphae make spores, the equivalent of seed. And by looking during the right time of fall, Koziol said, "I have found spores in every soil I have ever collected." She filters them out with fine sieves. Spore diameters run from 38 to 500 micrometers, the largest just visible to the naked eye – "If you are young and have great vision." But she said, "I can float the spores in water and you can actually see them moving around."

After this the work demands more learned skill. With a microscope she identifies species by spore size, color, shape, and "ornamentation." Most spores are spherical and yellowish. Some are oblong, and colors include black, white, red, and brown. Some are loaded with balls of lipids. Those with no pigment in the outer layer appear to have halos. Identifying marks include spots, bulbous or flat, from where the spores formed on the hyphae. Learning to recognize species by spore took long practice, but for Koziol it's now as easy as identifying plants.

Next comes growing the fungi for experiments or to inoculate fields. Some plants, including the brassicas – cabbage, rutabaga, turnip – have no use for symbionts. But Walter Jehne and Phil Lee, Australian soil microbiologists, said in The Natural Farmer that 98 percent of plants can benefit. And while some mycorrhizae are generalists, some plants grow better with particular fungus species. So Koziol plays matchmaker. In addition, since plants favor particular environments, she mixes a soil home for both the vegetation and the mycorrhizae.

To avoid competition between fungi, she sterilizes pots and growth medium, and inoculates each pot with one species. She must harvest each species' spores at the right time, which ranges from three to 10 months after inoculation. Then she combines species to make a fungal community. The whole process from original soil to a mixture of mycorrhizae of enough bulk to inoculate a new field occupies a couple of years. The work takes focus, feeling comfortable while dirty, and the strength to haul buckets loaded with 50 pounds of soil, plants, and fungi.

And there's psychological stress. KU eventually built a greenhouse just for fungi, but Schultz and Bever first had to share space with other researchers. The old greenhouse leaked, and rain could splatter fungi from isolated pots and make them contaminants. To find whether there had been infections could take a year, and getting research back on track could take three. Fortunately, Koziol, still in Indiana, was growing backups.

Mycorrhizae are unlike mushrooms and other fungi that fruit within view: they spend all of their lives underground. There they cycle through two forms, hyphae growing as threads through the soil, and spores waiting out winter. The spores don't result from sexual recombination, but from straight DNA copying. And some hyphae can segment into clones. "The asexual thing works for them," Koziol said. This might be because of how closely these mycorrhizae live to and utterly depend on plants. Recombining DNA and scattering spores through the air like a mushroom could be risky behavior, changing what host plants need and recognize, or placing the fungus with an ill-suited host.

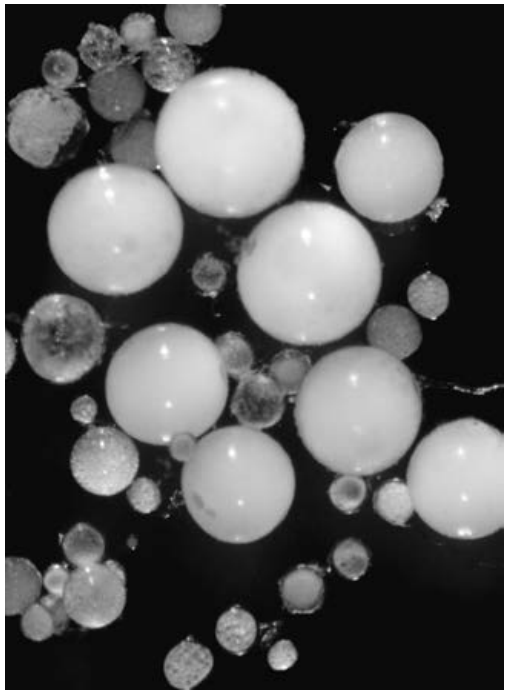
But the inner workings of arbuscular mycorrhizal fungi – AMF – are far from monotonous or inflexible. "The genetics of

AMF are super, duper strange," Koziol said. "They aren't like us. AMF can have hundreds, thousands of nuclei in a single-celled spore." And each of these nuclei within one cell can be different. "Basically, the genetics of AMF make them seem like they are many individuals at a single time. They're really weird. Almost like aliens." The accumulation of nuclei comes in hyphae mergers. This can give a species more genetic variety in one cell than the difference between it and another species. From such a vast repertoire, particular nuclei might go where they work best in different spots in the rhizosphere – the root world. Fungi can sense plants that give them more, and vice versa. "Plants and fungi have evolved elaborate signaling," said Bever, Koziol's mentor.

With this kind of life the concept of species becomes complicated. Some mycologists argue that there are only a few AMF species – or "operational taxonomic units." Koziol said, "It's a complete mess." But there are differences, as seen in consistently distinct spores, and in her connecting them to markedly different effects on plant growth.

Mycologists originally could identify species only by looking at spores. Now it's economical to use DNA reads, whether of spores or hyphae. Each technique has limits. Knowing spores is a trained skill, and still open to error. "Using DNA, you can extract a sample and basically ask the Internet and the libraries of genetic information that others have built what species you have, and it can give you a guess," Koziol said. "Sometimes it is very accurate, sometimes not. It depends on how well that library was built." Bever said, "The taxonomy of AMF is very much in a state of flux." More than 300 species have been identified, and this is only a fraction of a taxon as old as terrestrial plants. "It has deep evolutionary divergences," he said. Most of the unknowns live in natural realms like unplowed prairie.

A plant can have in the soil more than enough of everything else it needs to grow, but be held back by lack of one nutrient – or by the plant's ability to get it. Often this limiter is phosphorus. Roots may draw some phosphorus directly from the soil, but Koziol suggested that many plants find it worth paying from their carbon stocks for mycorrhizae to mine and share scarce phosphorus. Species such as pale purple coneflower and rattlesnake master have thick, coarse roots and relatively few root hairs to explore and expose to the soil. The fungi make enzymes to break down nutri-



The spores of arbuscular mycorrhizal fungi. This is how the fungi overwinters, as plants do with seed. Their shape, size, color, and other features help scientists identify the species. Jim Bever photo.

ents, which are absorbed by hyphae finer and with more surface area than roots. "It's a trade-off," Koziol said. "Early-successional plants tend to be less mycorrhizal and have finer roots. These plants may be colonizers and be traveling to areas with unknown microbial communities. Many late-successional plants are strongly mycorrhizal, growing eight, 10, even 20 times larger with prairie microbes. These plants are often constrained to existing in late-successional soils, such as remnant prairies, which have strong mycorrhizal communities."

Both early- and late-successional prairie plants are desirable. Early plants can cover and hold soil within a year of seeding. But a field of nothing but big bluestem and goldenrod – a restoration result that Koziol has seen – is not a field of healthful diversity. And even with seeding to match the species found in a neighboring remnant, decades-old restorations still often lack late-successional plants. That rarity interests Koziol, and is something that she thinks the right mycorrhizae can overcome.

In poor soil like sand dunes, she said, "Plants need fungi to help collect every little nutrient they can." She finds mychorrhizae in all sorts of soil, including the rich earth built by Midwestern prairie. But most Midwestern soil has been pushed toward dune quality, by farming. There is at least one mycorrhiza species that actually increases with tillage and fertilization. It's a common inoculant at garden stores. (Putting it on a disturbed field is probably a waste, Koziol said.) But most species do not reproduce well after disc or plow chop their hyphae. The state worsens under crop monocultures. "If that plant is a poor host to mycorrhizae, or a poor host to *some* mycorrhizae, then the mycorrhizal abundance can decline and species can be lost," Koziol said. "My work aims to find these species – the ones that are common in undisturbed systems and missing in disturbed systems." And then to try them as keys to healthy soil.

Finding a role for arbuscular mycorrhizal fungi in The Land Institute's new kind of farming, of perennials, ideally in plant species combinations, is Koziol's goal at KU and on land just west of Lawrence. She is part of the Perennial Agriculture Project, with funding from the Malone Family Land Preservation Foundation. Her studies are young, but she shared early preliminary results. One is that the fungi appear to boost alfalfa growth. Alfalfa serves as a nitrogen-fixing companion to perennial grain crop candidates, and might be bred to make seed for food. The fungi also appeared to help silphium, a sunflower relative being turned into an oilseed crop. Silphium made larger rosettes, the circle of leaves at the plant's base, and more leaves. And perennial sorghum set more seed.

Sorghum in the generously watered, temperature controlled greenhouse didn't grow better with mychorrhizae. That it did in the field shows the importance of fungi in real-life resource scarcity. Koziol saw similar results with annual sunflower. There was no difference between plants with and without mycorrhizae until drought, when the inoculated plants won. Koziol imagines that though the sunflower and other crop plants can host mycorrhizae in their roots, they have been bred or adapted to grow well with or without helpful fungi. "It's the whole early-successional thing," she said. "Ag plants are early successional."

That is, annual ag plants. The strategy for perennial grains, in ground left undisturbed for years but probably not for decades, can be called "mid-successional." (With enough rain, really late-successional cover will be a forest.) But these crops-to-be

are as yet grown in early-successional soil. "You can't count on fungi if you are being planted in a greenhouse pot or planted in a disturbed field every year," Koziol said.

Mycorrhizae can be parasites, taking carbohydrates from plants without giving anything. Such plants tend to be early successional. Their growth is curbed by at most 30 percent, and often less. But benefits to partner plants can be almost 25-fold higher, Koziol said. That doesn't mean monster onions. It means that without fungi, plants fail to grow much outside of their seed reserves, and will be outrun and die. "They can't get their foot, or root in this case, in the door because the partners they require to support them aren't there."

The Land Institute's other grasses being turned into grain crops, intermediate wheatgrass and perennial wheat, have not yet shown benefit from Koziol's fungi. But if alfalfa makes more biomass and fixes more nitrogen, it could feed them as a companion crop. Mycorrhizae can also strengthen soil against erosion, and might increase carbon moved from atmosphere to earth, softening climate change. "These are all things we need to test in the coming growing seasons," Koziol said. If mycorrhizae feed plants more phosphorus, nitrogen, and other soil nutrients, Bever said, the fungi should also affect what perennial grains pack to feed us. This is territory even less explored.

Simply switching to no-till farming of current annual crops, though it takes herbicides, allows mycorrhizae to recover from tillage. Some likely have been wiped out and need reintroduction. Which species will be best for the new perennial crops, and how to inoculate them, is still in R&D. The spores might go in soil plugs for dropping into the ground, or might be drilled into the soil with seed. Another challenge is cultivating the fungi at a scale to repopulate world croplands as they are converted from annual to perennial grains. Koziol's plots show that inoculated plants spread very slowly.

But arbuscular mycorrhizal fungi were crucial in building the rich soils that humans have mined as farmers of annuals. Now these fungi could be crucial for perennial grains to restore that capital and resilience. "We must stop thinking it's just the plants," Koziol said. "Tons of things are going on in soil."

Dyeing and squashing spores helps reveal features such as membrane layers, to help researchers identify species. Liz Koziol photo.

Extracts

OH, HOW CAN I RECAPTURE IT – that utterly right, homecoming sense of recognition? It seems to me now that the whole day was like an avenue leading to a home I have loved once but forgotten, the memory of which was coming back so dimly, so gradually, as I wandered along, that only when my home at last lay before me did I cry: "Now I know why I have been happy!"
– Dodie Smith, "I Capture the Castle"

THAT SEEING, understanding, and respecting people in their own landscape is crucial to their culture and way of life being valued and sustained. What you don't see, you don't care about.
– James Rebanks, "The Shepherd's Life"

PARTS ARE FICTIONS of language, of the calculus of looking at the world through a net which *seems* to chop it up into bits.
– Alan Watts, "The Book"

NOTHING SPURS human creativity like good and firm restrictions. – Jan Sokol, "Thinking About Ordinary Things"

I HAVE NEVER MET a successful dairyman who was not fairly gentle and peaceful by nature. If only presidents and kings had to milk cows as part of their training, half of our silly wars would never happen.
– Gene Logsdon

THE SEED of a future composition usually reveals itself suddenly, in the most unexpected fashion. If the soil is favorable – that is, if I am in the mood for work, this seed takes root with inconceivable strength and speed, bursts through the soil, puts out roots, leaves, twigs, and finally flowers: I cannot define the creative process except through this metaphor. – Peter Ilich Tchaikovsky, in Mason Currey's "Daily Rituals"

THE BEST national health policy is good agricultural policy.
– Soil ecologist Christine Jones

O UNIVERSE! What thou wishest I wish.
– Marcus Aurelius

I WAS LOOKING at a plant with a spread of leaves; and it seemed suddenly plain that the flower itself was a part of the earth; that a ring enclosed what was the flower; and that was the real flower; part earth; part flower. – Virginia Woolf

THEY WERE CURSING Roosevelt for the intrusion into their lives. At the same time, they were living off it. Main Street still has this fix. – Ed Paulsen, in Studs Terkel's "Hard Times"

CITING KENNEDY'S CALL to ask what you can do for your country: I think people have been asking and nobody's given them anything big to do. We underestimate people all the time. People want to make a difference, and they want to make a big difference, and they want to do something epic and heroic in this lifetime. Sometimes they don't even know it until you show it to them. – Dan Pallotta, author of "Charity Case," on the TED Radio Hour

In remaking civilization to something ecological, barns might again fill with hay to fuel traction. What certainly must happen, Fred Iutzi says, is for the growth economy to end, and for the industrial world to relearn how to enjoy modest bites of energy. Photos, including this barn in Sedgwick County, Kansas, by Scott Bontz.

Economic transformations for an ecological civilization

FRED IUTZI

The first recorded use of the word ecology was in 1866 by German biologist Ernst Haeckel. It is derived from the Greek *oikos*, which means home or dwelling place, and the Greek *logos* and *legein*, meaning to gather, recount, or say. Of course, *logos* has also come to imply directed inquiry or science. So we can play with literal interpretations of the word ecology to layer on meaning: "talking about home," "the science of dwelling in a place," or "the story of where we live."

Closely related to ecology but much older is "economy" or "economics." It starts with the same *oikos* for home, and then takes on *nomos* and *nemein*, to distribute. For the ancient Greeks, *oikonomia* meant household management or stewardship – literally, the distributions and allocations needed to manage a household, or metaphorically, doing the same in a community or a nation. Either way, the connotation was wise, competent, and thrifty management by the *economos* – the individual who acts as steward.

A current, suspiciously connotation-free dictionary definition of economics goes something like, "the production, distribution, and consumption of goods and services." But economist Lionel Robbins, writing in 1932, gave a definition perhaps more intelligible to ancients and moderns alike: "human behavior as a relationship between ends and means."

So the way we manage our household – economics – is by marshalling means and ends, ideally with prudence. But if we take stock of the "story of where we live" – ecology – we find that more often than not, the household is falling apart at the seams. We find that more often than not, we have lost sight of the ends we seek, and we make our choice of means with little regard for the unwanted ends that may be produced. We strive for food and get soil erosion and polluted water. We strive for a feeling of safety and produce oppression. We strive for convenience and get a warming planet.

The truth is, we don't know what we're doing in this civilization of ours. We've unmoored ourselves from past technological and energetic limits, but we haven't learned to swim the waters we now find ourselves in. Our decision making has become abstract, isolated, deranged. We need to reintegrate "the story of where we live" into our culture and our society. We need a truly ecological civilization. To get there will require a profound reordering of means and ends and the institutions that mediate them. To get there will require economic transformations at every level of society: how we grow, how we make, how we trade, how we shop, how we own, and how we govern. How on earth will we do all that?

"We put over a hundred million feet of logs in the river. It came off one 40 of tim-

ber that grew and peaked like an Egyptian pyramid. We didn't know the country, but Bunyan was sure we'd hit one mill or another downstream, and didn't give a hoot which one, since logs were the same price everywhere. After running that drive for four weeks, we passed another camp that had cut a steep hill 40. After another month we hit another deserted hill 40, and Bunyan began to swear, because he saw all this lumbering sink the price of logs. But after four more weeks and another hill 40, we realized it was Round River." So goes the old Paul Bunyan story.

Here I'll let Aldo Leopold, in an essay called "The Round River: A Parable of Conservation," take over: "We of the genus *Homo* ride the logs which float down the Round River, and by a little judicious 'burling' we have learned to guide their direction and speed. This feat entitles us to the specific appellation *sapiens*. The technique of burling is called economics, the remembering of old routes is called history, the selection of new ones is called statesmanship, the conversation about oncoming riffles and rapids is called politics. Some of the crew aspire to burl not only their own logs, but the whole flotilla as well."

After this wry commentary about our Paul Bunyan economy, Leopold proceeds to his main point about ecological processes. "Wisconsin not only *had* a round river," he wrote, "Wisconsin is one. The current is the stream of energy which flows out of the soil into plants thence into animals, thence back into the soil in a never-ending circuit of life." Leopold highlights energy, but of course we could talk about cycles of nutrients, carbon, genetic diversity, and so on. All of these exemplify how ecosystems and the ecosphere are beautifully circular – in the sense of "unbroken circle," "perfect circle," or "virtuous circle."

Our economic systems, in contrast, tend to be perversely circular – think "circular logic," "circular firing squad," or "vicious circle." This is reflected in the fuzziness of the economic ends we seek. Like Paul Bunyan's crew fruitlessly driving logs in a circle, the process takes over. The objective of agriculture is for people to be fed. But the abstract concept of wealth creation in a laissez faire economy has become the product, and farmers and eaters both fall by the wayside. The objective of things like houses and clothing is for people to be sheltered from the elements. But what dominates is something like a consumer products arms race. And so we burn daylight – fossil daylight – while the planet warms. The perverse circularity of the economy ignores or subverts the beautiful circularity of the ecosphere.

The confluence of these two confusions – about ends and about means – is exemplified by our focus on Gross Domestic Product, GDP, as our key economic indicator. GDP is the final market value of the goods and services produced within a country by its citizens. Its precursor measure, Gross National Product, was conceived of

Brigitte Schropp, left, from Langgoens, Germany, and others at the Prairie Festival heard about embedding good economic behavior in culture, via ethics.

as an expedient way to compare economic performance in the climb out from the Great Depression. The author of this metric, Simon Kuznets, was famously on record as early as 1934 cautioning against misuse. He pointed out that the statistic ignores economic activity outside the marketplace, the wealth inequalities, and the experiences of the actual human beings involved, and concluded that "the welfare of a nation can, therefore, scarcely be inferred from a measurement of national income." Economist Kate Raworth translates some of Kuznets' further remarks into the late 20th century language of systems analysis. Measured in isolation, national income is a flow with no accompanying stocks – with no accounting for the ecological wealth from which income is extracted, or for consequences of that extraction. I'll tell you what I call a flow imposed with no regard to the stock on either end: a wound.

Six years ago that same UK economist Kate Raworth debuted the Safe and Just Space framework for thinking about how we are called to live on the planet. A "safe" existence is one that avoids violating any critical planetary boundaries: atmospheric CO_2 concentrations, nitrogen and phosphorus cycling, nonrenewable resource extraction, and the like. A "just" existence is one where the vast majority of people on the planet attain certain minimum standards of nutrition, health status, energy availability, etc. Raworth plots these safety criteria on a round diagram and the justice criteria on another round diagram, and then overlays the two. Plotting the minimum acceptable level of human wellbeing and the maximum tolerable impositions on the planet defines the space we can safely and justly operate in as a civilization. The shape of that space supplies Raworth's tagline and the name of her book: "Doughnut Economics."

In the journal Nature Sustainability, researchers from University of Leeds in England assessed that humans are far from fitting in the doughnut. For five out of the 11 human wellbeing indicators they used – including life satisfaction, health, and sanitation – not one country in the world meets the minimum while simultaneously staying in-bounds on the sustainability metrics. For the other six wellbeing indicators, only a handful of countries are pulling even one of them off sustainably.

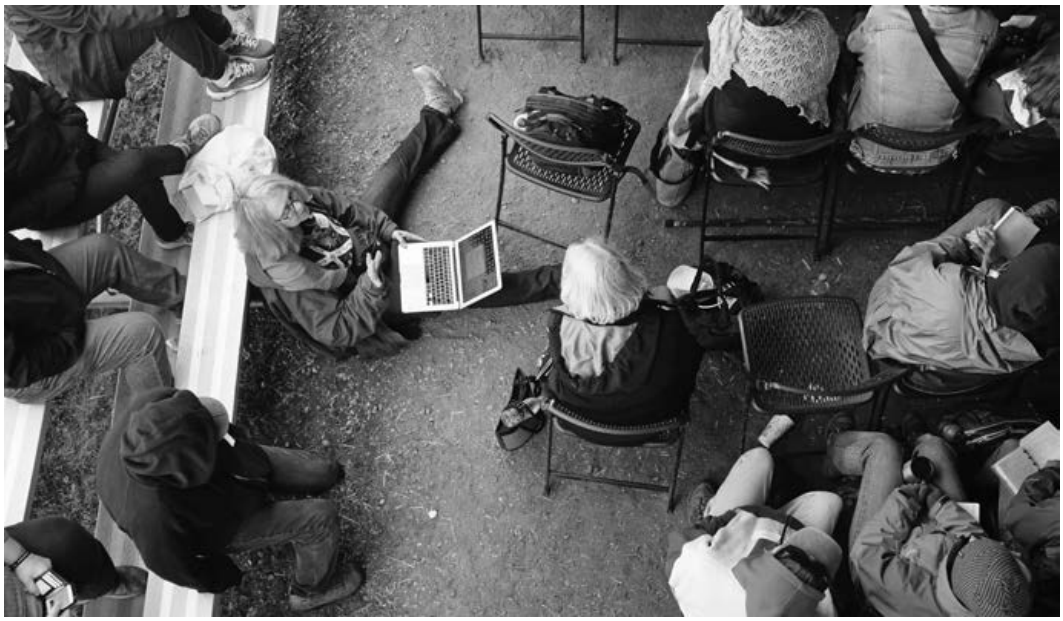
Here's a hard implication: the conventional progressive toolbox for making the economy more sustainable isn't cutting it. I mean things to reduce the tight coupling of economic activity with planetary extraction – things like integration of renewables into the current energy economy, replacing gas engines with hybrids, installing water efficient toilets, and using the proverbial squiggly lightbulbs. All of these things happen in a growth economy, and so all will ultimately prove inadequate. Now, inadequate does not mean ignoble or unnecessary. Just as adopting the best possible organic farming methods with annual crops helps slow the rate of resource loss to buy us time to develop perennial grains, other "bright green" efforts can be regarded as necessary to buy time for deeper transformations of the economy. Decoupling strategies, as far as they go, are helpful and necessary and therefore noble. But they are hopelessly insufficient. This is not a situation where we can insert one or two technological fixes and a new law or two. Our thinking and actions must change profoundly.

What we need is no less than a transition to an ecological civilization. What is a civilization? Well, shoot, it's progress. Boy and girl meet annual grass, boy and girl domesticate grass into a grain, then settle down, urbanize, socially stratify, arts and letters blossom, a people-nature dualism

flourishes, and they all live happily ever after, or at least until the resources run out. What, in contrast, is an ecological civilization? I propose two criteria. One is that the marshaling of means and ends – which is to say economic actions – by individuals, households, and society be deeply ecologically informed, to respect planetary boundaries and the wellbeing of fellow dwellers on it. In other words, live in the doughnut. The other is that the impulse for economic actions to be good, ecologically informed, and compassionate should be woven into the very fabric of culture, and not dependent on maintaining an extremely high rate of good decision making by individuals over a long time. In other words, make it doable for people who aren't saints.

So what does this require of us? First, we need an end to global economic growth. All that we know of history, all that we know of biology, and all that we know of earth system science tells us that economic activity can never be decisively, thoroughly decoupled from impacts on the ecosphere. That is enough to tell us that infinite growth is a nonsense concept. But at this point, merely ending growth will not be enough – we will need to tackle economic *degrowth*.

Back to that Nature Sustainability paper, and how for most of the human wellbeing indicators only a handful of countries achieved the minima while simultaneously not overdrawing on the ecosphere. If we were to cobble together a hypothetical sustainable, minimally prosperous country out of the lot, we would have the nutrition pathway of Eritrea; a sanitation pathway that hasn't yet been demonstrated, but where Tajikstan is the closest fit; the median income and energy use pathways of Moldova; a health pathway that hasn't been demonstrated, but where Vietnam is the closest to fitting; the secondary education pathway of



Prairie Festival-goers heard that key to the new economy is cooperation.

Sri Lanka; the equality pathway of Ethiopia; the full employment pathway of Rwanda; and pathways to democratic governance and to overall life satisfaction that have not yet been demonstrated by any country. Notice anything about that list? Not much Global North on it. We will need degrowth as a planetary civilization overall, and we will especially need degrowth here in the rich countries to make it possible for our southern neighbors to climb out of the colonial trench. The good news is that in that process our southern neighbors may be able to teach us a thing or two to aid our transition.

Second, as we contemplate degrowth, we need to develop a sense of sufficiency. As Wes Jackson points out, we've evolved to like our num-nums – easy carbon. And the drive to satiate our big brains' complex and abstract desires hasn't faced much selection pressure against it – yet. So rather than the consumer arms race and the battle with the Joneses, we need to cultivate that sense of sufficiency – learning to take pleasure in modest amounts of energy intensive goods and services, and an overflowing abundance of beautiful relationships with one another and with the ecosphere.

Third, we need to embed good economic behavior into culture. The main way to do that is ethics. A very familiar passage from Aldo Leopold applies here: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." But we can go back considerably farther than the year Leopold was writing, 1947. Dotan Leshem writes: "Both ancient Greek *oikonomia* and contemporary economics study human behavior as a relationship between ends and means," but while modern economics is largely neutral about ends, "in ancient economic theory, an action is considered economically rational only when taken toward a praiseworthy end." Praiseworthy ends included careful stewardship of the family, household, and farm, contributions to public institutions, support for friends and neighbors of more limited means, and creation of leisure time for good governance, arts, and letters. Unpraiseworthy ends included self-aggrandizement, excessive luxury, and poor stewardship. A related concept is that economics referred only to careful stewardship of practical matters – Aristotle articulates a whole separate and less virtuous discipline, *chrematistics*, for the art of acquiring wealth. Indiscriminately plowing your wealth back into creating more wealth for yourself fell in the province of *chrematistics*, not economics. So one might say Artistotle advocated a no-till economics.

Fourth, we need to be prepared to make cooperation the fundamental building block of our economic activity and reasoning. We have developed a cult of *Homo economicus* that does not represent the actual behavior of actual human beings very well at all. We are neither coldly rational nor coldly self-centered. Millions of years of evolutionary history have prepared us to relate to one another affectionately and collaboratively. In many chapters of history this cooperative spirit at the levels of family and society has been a norm, and today we still see it break through when the chips are down. An economy more explicitly founded on cooperation will include better recognition of the labor that's already performed outside of the legible economy. It will include forming business entities as cooperatives – enterprises that are jointly owned by the people who benefit directly, and that are governed on a strictly equitable basis. As David Bollier suggests, it will include holding various kinds of property in the commons.

Fifth, we have to figure out who makes decisions and how. Democracy as we cur-

rently conceive it is clearly better than the authoritarian alternatives that are frequently counterposed to it – but is it good enough? Is it the best we can do? We are challenged on this score by writers like Loka Ashwood and James Scott, who ask whether majority rule democracy is capable of truly respecting minority rights. They also point out that we have not done well orchestrating big, fancy interventions from afar.

This brings us to localism. It's easy to grasp that there are resource use efficiencies available to local economies, and that there are opportunities for local decision making to cultivate and draw on local wisdom and a local culture. Relocalizing our economies will be critical for getting back into the doughnut. But local is not a panacea. Shorter transportation distances are usually less energy intensive than longer ones – but occasionally they're not. Local, participatory decision making theoretically has large advantages over governance from afar – but sometimes local decision makers simply replicate the same biases that were already being projected from the far off capital. So while we continue developing critical local foods and local economies, we must learn how to make those approaches truly work, and to see when they don't.

How do we make the transition from the economic sensibilities and systems we have to the economic sensibilities and systems we need? This is a daunting task. A small handful of problems are solvable using the existing levers of political process at the national level, so political advocacy is constructive. Organizing locally will help us solve another handful of problems now – but more importantly it will better equip us to envision the future we want when all else fails. Likewise organizing locally will help us better advocate politically now – but more importantly it will better equip us to implement what we want when all else fails.

To connect this transition with my two opening circularities, the virtuous and the vicious, I'll use a metaphor. Traveling spacecraft often take an elliptical orbit. When the destination nears, a rocket thruster is fired to circularize the orbit – to take an orbit that no longer swings wildly around, but keeps close by the home neighborhood. That so-called "circularization burn" consumes a large amount of scarce fuel, but positions the craft so that from then on physical forces maintain its relative position for free. Kate Raworth writes, "Ours is the first generation to deeply understand the damage we have been doing to our planetary household, and probably the last generation with the chance to do something transformative about it." So as a civilization we have the opportunity now – maybe our one and only remaining opportunity – to perform a circularization burn. At The Land Institute we are using technologies made possible by cheap fossil fuels to develop crops that will scarcely de-

Colin and Craig Bramhall, of Omaha, biology and environmental science majors at Doane University, are among decision makers of the future.

pend on fossil fuels. The same logic arguably applies to economic thought and experimentation – we should get cracking now while we have the energetic slack to wing ideas freely around the globe.

So in conclusion, understand that changes will be necessary:

1. End of the growth economy.
2. Develop a sense of sufficiency.
3. Embed good economic behavior in culture via ethics.
4. Cooperate.
5. Make decisions in a just and appropriately scaled manner.

If we can perform this civilizational "circularization burn," maybe we can get out of the perverse circularity of our current economics, of hunger for fulfillment, of great wealth and deprivation, and of a failing planet. Maybe we can craft for ourselves an economic circularity that mimics and interlocks with the elegant dynamic circularity of nature, with the "stream of energy which flows out of the soil into plants thence into animals, thence back into the soil in a never-ending circuit of life." Maybe at last we can reconcile our ecology and our economics. The story of our life in this place can guide the stewardship of our life in this place.

Iutzi is The Land Institute's president. This is adapted from his talk at the 40th Prairie Festival, held September 28-30. To hear the full talk and others, go to youtube.com, and search for Land Institute. For an order form and CDs, email Amanda at wagner@landinstitute.org or call 785-823-5376.

Homework

What kind of ancestor do you want to be? At the Prairie Festival, Brooke Hecht, of the Center for Humans and Nature, and Aubrey Streit Krug, of The Land Institute, considered that question. Then they invited listeners for questions to carry from the festival and apply to making an ecological civilization. Here are some of them.

- What would be a holistic, ecospheric way to think about elders and their role in the work of healing the world?
- How can I lose some of my ego and stop thinking about money and material things, and start thinking about better values?
- How can we carry forward with feelings of discomfort about the world's state combined with our strengths, influences, and a sense of joy?
- How can we communicate our joys and successes with each other?
- What kind of government does our country need to form for change?
- How do we talk with young people?
- How do we bring principles of nature and fellowship into flawed civilizations and human nature?
- How do we teach the satisfaction of sufficiency in a society that celebrates acquisition?
- How do we make these questions our homework?

To which Streit Krug encouraged further questions and conversations with her and with Hecht. One route is the Center for Humans and Nature's online feature called Questions for a Resilient Future.

Anna Andersson, whose upbringing melded life in Sweden and the US, also has twin interests in music therapy and sustainable agriculture. She sees these similarities: Both are complicated. Both serve an ecological role in our health. Both address the root of a problem. Photo by Land Institute intern Dan Patel, who grew up in New Jersey and this year earned a bachelor's degree in environmental science from the University of California, Los Angeles.

A servant of curiosities

Anna Andersson pursued music therapy but was drawn back to agriculture

SCOTT BONTZ

Anna Andersson grew up in Arthur, North Dakota, a town of about 400 in the Red River Valley, with soils made fertile by silt deposits of Lake Aggasiz at the end of the last glacial period.

Her father, Ola, advised farmers as an agronomist for a local grain elevator company. Ola had grown up on a farm in Sweden. It was just one farm, but a sharp contrast to the industrial corn and soybean agriculture that dominated eastern North Dakota. Anna's grandfather, Carl-Erik, grew wheat, barley, oats, sugar beets, potatoes, and canola, and, on a smaller scale, vegetables. He raised cattle, pigs, and sheep. His fertilizer was manure. He spent most of his time outside, and Anna admired his intimate sense of place, his awareness of details such as the calls and migration of birds. She described him with livestock as "open to impression, rather than imposing something." Listening, being still. "He was careful in his proceedings with the natural world," she said. "That was really a powerful role model for me." She is glad to have experienced as a child the contrast between Carl-Erik's farm and the agriculture around Arthur. It eventually helped bring her to study food production and explore alternative ways of farming.

She's also glad for growing up with two cultures. Her mother, Karin, grew up in Illinois. Karin and Ola met by international exchange as members of 4-H. Anna and her twin brother, Erik, were born in Sweden and stayed for five years. Their parents wanted them to experience both worlds, and moved when Ola found agronomy work in North Dakota. Karin worked as a computer programmer. The parents each could speak the other's native language, and their upbringing of Anna and Erik was intentionally bilingual. The more singsong, vowel-mixing Swedish gives Anna a second sense of the world. She feels most fluent when she is among people who know both languages. She'll speak mostly English, and use Swedish words to "paint with nuance."

Every summer Erik and Anna returned to Sweden, in the southern province of Skåne. They helped on the family farm, immersed in Swedish. Erik learned from his grandfather, and now farms in North Dakota. Anna explored well beyond the farm, "a servant of curiosities."

At the University of North Dakota, she earned a bachelor's degree combining music and psychology. She moved to San Diego for work as a music therapist in psychiatric units, schools, and hospitals. But her curiosity about agriculture – especially an agriculture that is healthful, like music therapy – became "too strong not to listen to."

She went back to the family farm in Sweden. Her grandfather had died, but she helped her uncle. She learned to drive a tractor, worked cattle, raised a year of crops. She added a generation to the many that

"I'd rather see people around me daring and failing than locked in fear." – *Anna Andersson*

have cleared glacial rock deposits from family fields. She reckoned the average age of her social circle at over 60.

She also took night classes at nearby Lund University, in sustainable eating systems and gastronomy. Now she's a year into another bachelor's degree, in physical geography, wanting experience in natural sciences, to look at agriculture a new way. That new way brought her to The Land Institute in July, as an intern.

There'd been short holiday visits to the US, but this was her first long time away from Sweden in three years. With that and improved literacy in the natural world, she said, "I felt like I was coming back with new eyes. It's been fun to rediscover my home biome." Of walks amid big bluestem and other prairie grasses, she said, "I would just go and bask in the technicolor sea."

The description builds from a love developed in Sweden for the ocean's dynamism and vastness, after growing up in North America's center, as far as one can be from the sea. Now she sees the prairie's expansive sky and quietness as exotic. And – sounding wondrous, not depressed – she feels an insignificance similar to when a tour by her college music trio put her amid the throngs of Shanghai, Tokyo, and Seoul.

Travel also took her to work on Italian farms. She learned about ancient grains and saw the importance of biodiversity to farming. She saw how Italian farm food "spoke of the landscape," with plates bearing what's available in place and season. She'd rather abstain from hothouse tomatoes, and instead eat and celebrate root vegetables. On a winter solstice campout in Sweden, she and friends cooked, in flaming bourbon, a pineapple. But they'd found it in a dumpster, and they labored for three hours to start a fire using damp birch wood. Then, she said, "It was absurd and so lovely."

She could also find tropical fruit on a hiking trip in the Faroe Islands, remote in the north Atlantic between Scotland and Iceland, but now globalized. What struck her, however, was human lives set against basalt pushed from the sea 55 million years ago and bearing as yet a film of topsoil good enough only for sheep. And there were the delights had by trusting strangers. One was a shepherd who directed her to trails she would not have discovered, and who kept an eye on her from his home as she traversed the summit solo. Another was a lonely driver who picked her up, gave her a tour of the island, and took her home to dinner with family. Of the shepherd she said, "I hope to be that same guide when I get the chance."

In talk about caution and creativity, she told of hearing a college student ask at The Land Institute, What is creativity? Legume breeder Brandon Schlautman answered that the institute is imagining an agriculture that does not yet exist. "That's one thing that really attracted me to this place," Andersson said. She offered, "Focus on curiosities rather than comfort. I'd rather see people around me daring and failing than locked in fear." Caution has its place, but taken too far, it becomes stifling, with all exposures planned and controlled. "When you open yourself up to the world and people around you, anything can happen."

Dialing sun, earth, and carbon

Artist Owen Brown at the October 26 dedication of his painted aluminum sundials and Osage orange companion posts decorated with string and seashells. "Units of Measure," at The Land Institute's Marty Bender Nature Area, are three sundials each at three sites, lines between which make a right triangle. The east-west side of the triangle is 1,190 feet, the distance that Earth here rotates in one second. The north-south side is 723 feet, and the third site is placed so that the shadow from sundials there points to the "second-later" point at dawn on the summer solstice. The dial poles are 15 feet long, the approximate length of our crop plant intermediate wheatgrass. The wood posts are placed where the dawn shadow falls when atmospheric carbon turns negative in spring with increasing photosynthesis. The date has trended later since the industrial revolution. To show that change over the coming decade, Brown has provided more posts for other visiting artists to decorate. "I want this installation to make us more aware of where we are, who we are, and how we are," Brown said, " in relation to the earth, to what we grow, and to what nurtures us." Brown's paintings can be seen at eyesvoice.com. Scott Bontz photo.

Land Institute shorts

Making hay with grain

Cutting intermediate wheatgrass for hay increased forage yields without lowering grain yields during three years of study at nine sites from Alberta to New York. So this perennial grain crop being developed at The Land Institute might profit farmers two ways. The study was coordinated by Steve Culman, a former institute graduate school fellow and now Ohio's soil fertility specialist, at Ohio State University. Wheatgrass plots were mowed twice, once, and not at all. Grain yields dropped considerably over the three years, an ongoing challenge with wheatgrass. But dual-use plots made more grain than did plots left uncut for hay. The average hay yield average across the sites fell more than 16 percent in the second year, but in the third year largely rebounded. The mowing appeared to increase root biomass and nutrient cycling, which can improve production.

Ex-intern leads ag department

Adam Davis, a Land Institute intern in 1991 who went on to develop ecological weed controls, has been appointed professor and head of the University of Illinois Department of Crop Sciences. He is the first of our interns to lead a land grant university's agronomy program. Davis had worked 14 years for the USDA Agricultural Research Service at the UI campus in Urbana, meanwhile teaching as an adjunct. He is interested in UI collaborating with The Land Institute.

Growing up in New York City, it never occurred to Davis that he could have a career in agriculture outside a tractor cab. But while studying for his bachelor's degree at Yale, hoping to apply biology to improved stewardship of the earth, he increasingly spent time in the forestry school library, where he found a brochure for Land Institute internships. "I felt as though it was pitched directly to me."

Davis

Davis went on to earn graduate degrees from Brown University, University of Maine, and Iowa State University. In his mind was the institute's idea of farming in nature's image, but he applied it not to perennials or polycultures, but more generally, to "ecosystem services," for ecological agriculture.

Most of his career has been in weed management. Farmers have long killed weeds only after they appear, as seedlings. Davis's attack has been pre-emptive. Crawling through crop plots as a graduate student, he observed how insects, rodents, and birds could clean a field surface of 30 to 90 percent of weed seed. So, to encourage the granivores, delay as long as possible fall tillage, which buries seed. And give the animals protection, such as growing clover with wheat to hide mice from predators. Another tack is weed seed gathering by the farmer. Instead of having the harvest combine blow stalk, chaff, and weeds back on the field,

run the leftovers through a tow-behind machine that sifts out seeds and grinds them to dust. The Harrington Seed Destructor, named after the Australian wheat farmer who invented it, costs $180,000, and there are only three in the US, one at UI. But Davis said that in the works is a bolt-on version that will cost about $30,000. The device misses weeds that go to seed before harvest, but can capture 70 to 80 percent of those still on the stalk. You can learn more about ecological weed control at integratedweedmanagement.org.

The general challenge for agriculture schools now, Davis said, is teaching students how to balance the triple bottom line of profit, production, and environmental health. His university already researches perennial polycultures – not grains, but nuts and berries, in a project called Agroforestry for Food. To the same end a former UI student formed the Savanna Institute.

Board member Donnelley dies

Vivian Donnelley, a member of The Land Institute Board of Directors since 2009, died of cancer October 4. She was 71. Institute President Fred Iutzi said Donnelley had integrative vision and a knack at communicating it: "Vivian understood that the scientific aspects of our work to perennialize agriculture would be unintelligible to most people except in the context of the broader narrative about people, the earth, and sustainability. At the same time she understood that broad narratives about sustainability had little true meaning unless they were backed by doing something rigorous and effective about it, in our case the science."

Donnelley

Vivian Hilst was born in Hutchinson, Kansas, and attended college at Valparaiso University in Indiana before settling in New York City with her husband, Strachan Donnelley, who preceded her on The Land Institute board. She worked in admissions at New York's Dalton School, and served on the Dalton board. She was also a board member for Green Chimneys, a program of animal-assisted therapy for children, and for the Center for Humans and Nature, which Strachan Donnelley founded, and which works with The Land Institute (see page 21).

Brown resigns from board

After serving four years on The Land Institute's Board of Directors, Christina Lee Brown resigned, citing other demands on her time. Brown, of Louisville, Kentucky, co-founded The Berry Center to promote land conservation, small farms, and rural community.

Brown

Schneider joins development

A year after he joined The Land Institute as operations associate to Rachel Stroer, our chief strategy officer, Will Schneider was promoted in October to development officer. Development means fund raising, which Schneider had already helped with, and which now becomes his focus.

We are given a science library

Pioneering agroecologist Steve Gliessman donated to The Land Institute his library of about 2,000 books and scientific journals on ecology, agroecology, botany, and natural history. An estimated 4,500 pounds of publications are being unloaded and shelved at our field station 130 miles to the east at Lecompton, near the University of Kansas. "It's a really rich collection," said Research Director Tim Crews. Gliessman founded the agroecology program at the University of California, Santa Cruz. (And there affected undergraduate Crews's life course – see page 12 of the spring 2014 Land Report, available online) There isn't room for the library at institute headquarters in Salina, where most of the work is to develop individual crops, and Crews said the library's ecological bent is suited to the work in our fields near KU. The books can be used by visiting scholars as well as by institute and KU researchers. Gliessman retired from UC-Santa Cruz in 2012. He said he is busier than ever with agroecology, and "enjoying it even more." He is editor of the journal Agroecology and Sustainable Food Systems, president of the Board of Directors of the nonprofit Community Agroecology Network, and with his wife, Robbie, runs an organic wine grape and olive farm, Condor's Hope.

All old Land Reports are online

All 121 past issues of the Land Report are at landinstitute.org. Go to Learn, and then The Land Report. An issue is posted on the site when the next print edition is mailed.

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In August, Cosette Joyner Armstrong, right, brought 13 Oklahoma State University design students to The Land Institute and, 70 miles east, Konza Prairie Biological Station. This was for a short course in biomimicry, studying how nature's economy could be applied to the clothing industry. Joyner Armstrong designed and taught the course with Aubrey Streit Krug, our director of ecosphere studies. The experience was as much for instructors as for students, a lesson in how to bring about seeing the creative and destructive processes of the ecosphere, a system on which all other systems depend. Students said the best learning moments came from places – ecology – or experiences – hands-on or social. For Land Institute President Fred Iutzi's essay on changing the economy for an ecological civilization, see page 14 of this issue. For more about Joyner Armstrong's philosophy and work, see the spring 2018 Land Report, available at landinstitute.org. Scott Bontz photo.