Land Report

Number 125, Fall 2019 · 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

Intern Madeline DuBois loosens roots of intermediate wheatgrass while transferring plants from pot to field. Wheatgrass is the perennial that is used to make Kernza®, our registered trademark for food from the grain. The plants that DuBois helped set came from eight generations of wheatgrass development. Damian Ravetta, a collaborator from Argentina, has been studying how use of sunlight and water differs between wilder and more select wheatgrass. This study aims to clarify how these things may have changed with breeding for crop traits like seed yield. DuBois, from Poolville, New York, is an environmental engineering student at Northeastern University in Boston.

We were born for this

Our proclivity for change got us in a mess. We don't lack capacity to get out of it.

FRED IUTZI

Between the 20th and the 27th of September, more than 7 million people turned out to demand action on climate change at events around the world, swamping any previous record for environmental causes. According to Bill McKibben's 350.org, this included more than 6,000 actions in 185 countries.

But yet. We are now at a time of unprecedented climate peril – unprece-dented, at least, without shifting to geological time scales. Human activities from the industrial era to now have already caused a full degree Celsius of global warming. This warming "will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea level rises", according to the Intergovernmental Panel on Climate Change. This is the global warming we are locked into, even if the smokestacks dry up today. "Global warming is likely to reach 1.5 degrees between 2030 and 2052 if it continues to increase at the current rate". Effects include higher average temperatures almost everywhere, "hot extremes in most inhabited regions", excessive rainfall in some places, and drought in others. They include effects on plants, insects, and vertebrates, and the rather chilling phrase, "transformation of ecosystems from one type to another". In a rather understated sentence, "Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase". Translation: broken lives and broken ecosystems.

To avoid overshoot, global carbon dioxide emissions must decrease by about half by 2030 and hit net zero by 2050. In a less understated sentence, this will require "rapid and far-reaching transitions in energy, land, urban, infrastructure and industrial systems. These systems transitions are unprecedented in terms of scale".

I want us to sit with this for a minute. I think sometimes we get caught up with the idea of being a card-carrying believer in climate science, and we don't fully process the implications of the science we're so proud of believing. Friends, changes are coming.

Our bodies are two-thirds water, but after that the remaining third is almost entirely carbon compounds. We are, substantially, made of carbon. We take carbon in every day, and we breathe carbon out every second. So it's ironic that we've managed to get ourselves into a situation where the word carbon is fraught – half understood – with grave danger.

Facing page: Climate change is predicted to raise more violent storms, more often. It will do much more than rain out Prairie Festival bonfires. Palliation demands change quick and of unprecedented scale. Scott Bontz photos.

Part of the confusion is difficulty in grasping the time scales involved in the mass flows in our bodies and in our world and in our universe. "Now we learn what patient periods must round themselves before the rock is formed; then before the rock is broken", as Emerson wrote. But as much book learnin' as we now have about carbon cycles and flows, we're still struggling to fit the rhythms of our lives into them. On a time scale of months, years, and decades, solar radiation arrives on our planet; plants harness some of it to reduce atmospheric carbon to biomass; later they oxidize carbon back out when they decay or are digested. On a scale of tens of millions and hundreds of millions of years, sometimes a whole bunch of organic matter gets trapped deep underground and removed from circulation – fossil fuels. On a scale of decades and centuries, we come along, stick a straw down into that trapped carbon, light it on fire, and then act all surprised about the results.

That brings us to culture – arguably what makes our species distinctive from all of our other carbon-based companions.

Around 1740 Alexander Pope wrote, "Where grows? Where grows it not? If vain our toil, we ought to blame the culture, not the soil". This word culture has been in constant motion – in 1740 it was still more closely associated with farming than with a broad system of human beliefs, norms, and behaviors. The content of those norms and behaviors has been in motion too. And too often our culture has focused us on extraction and domination – of the earth and of one another. Naomi Klein calls the latest version of this "the gig and dig economy". But at the same time, culture can be a source of grace and resilience. Some urgency now exists to round off the rough parts and shine up the smooth parts. We need to reclaim some of what was lost from 1740 to now, and at the same time cast off the baggage that was brought forward. We need to put culture back to work for the ecosphere and the human beings, who are part of it.

This change can be seen as profoundly difficult. But ironically, if there is anything that our particular combination of carbon and culture has shown, it's that we also have a great proclivity for change – our agriculture, our transportation, our industry, our information processing and communications, our leisure – all of these things undergo a revolution every generation or two, and the energy intensivity goes up each time. So the bad news is, that proclivity for change is exactly the way we got into this mess. The good news is, we are not lacking in a capacity for reinvention.

Here are three human paradoxes to ponder. First: Climate action versus climate justice. On the one hand, the proximate forces causing climate change sit within physics and engineering and chemistry and biology, and the proximate solutions are logically going to come from those areas. Some might say, do we have time right now for concerns of social justice? For fighting racism and sexism? For elevating the status of indigenous peoples? On the other hand, everything we know about the world tells us that our earth domination complex is tightly intertwined with our people domination complex. Sometimes this is used against us, exploiting prejudices and inequalities to stop action. Sometimes we sabotage our own action by failing to consult the wisdom we could be drawing from marginalized communities. So maybe the real question is, do we have time right now not to fight for social justice?

Second: Cut the fossil fuels versus capture the carbon. On the one hand, the preponderance of our greenhouse gas emissions

come from burning fossil fuels. So maybe we should focus there, and concentrate our efforts exclusively on renewable energy and energy efficiency. On the other hand, what we really need is a good source of negative emissions – a solution that actively pulls carbon dioxide out of the atmosphere. But maybe, in truth, the climate problem is so large that we need both, with a big side of reduced demand as well.

Third: Fast versus slow. On the one hand, climate change demands rapid solutions like no other human problem ever has. We need to generate substantial reduction in greenhouse gas emissions immediately. We do not have time for slow solutions. On the other hand, some rapid solutions fall into a category also known as "quick fixes". And the culture of the quick fix is a big part of how we got into this situation. What we need instead is fast and decisive action on truly transformational solutions. Some of these, like fundamental changes to how we produce and consume energy, have the technical potential to be fast. Other transformational solutions, like perennializing our grain crop agriculture, are by necessity slow projects. So just as the gravity of the climate change situation tells us we don't have time to work slowly, maybe the gravity of the climate change situation also tells us we do not have time for quick fixes.

A story. When I was about seven years old and my grandfather was 67, he planted a California redwood in his front yard. This is a tree that isn't considered fully mature until it's 500 years old. Can you imagine the audacity, the vision, the commitment to the future, of planting a California redwood at age 67? Maybe there's a lesson for us there.

The coda to this story is that when I was about 11 and my grandfather was 71, the tree died – because if you know anything about redwoods, they don't grow in west-central Illinois! So the quality of our vision perhaps matters in addition to quantity. In fairness to my grandfather, I think he was perfectly well aware that this was extremely unlikely to work – he just wanted to see what happened, and after judging there was nothing at risk, he went ahead – not a bad way of being.

In our case, a bit more is at risk. What are we going to do?

Risk was in the air at the first Prairie Festival I attended, in September 2001. As I now understand, there was a real possibility there wouldn't be any Prairie Festival in that particular month of that particular year. But in the face of air travel confusion, canceled registrations, and national tension, the show went on. One of the speakers was Mari Detrixhe, a farmer who also has the distinction of having been the first person ever to preside over The Land Institute's board whose last name wasn't Jackson. With a little help from our archives, I can tell you one of the things Mari said on that day 18 years ago: "Truth … is entered through the twin portals of paradox and confusion. If we wish to take this path, we have no choice but to live with tension and complexity". And she closed with, "Above all, live the life you have been given".

The fastest and largest response is immediate policy action to start the phase out of fossil fuels. You can call it a Green New Deal, you can call it a new conservatism that focuses on conservation, you can call it a transition to an ecological civilization; it can start at the national, state, local, or affinity group level (though it has to finish nationally and globally); it can come from the left, it can come from the right, it can come from some weird four-dimensional political hy-

percube for all I care; but it has to be broad based, it has to be ambitious, and it has to be assured.

A good example is the cap & adapt framework proposed by The Land Institute's own Stan Cox, along with co-author Larry Edwards. The first main element is a managed ramp-down and phase-out of fossil fuel use, including a hard and steadily declining cap on fossil fuel emissions. Second is a national economic mobilization to build the maximum renewable energy and energy efficiency infrastructure. This will require a cultural transition from a luxury consumption mindset to a healthy sufficiency mindset. The approach can be tailored to any timeline, but the longer the timeline, the greater the cost in broken lives and broken ecosystems. That cost would be dramatically curtailed by a 100 percent phase out of fossil fuels by 2030.

All of this will require major policy change. But history tells us major policy change almost always has to be based on civic mobilization.

I could have said popular mobilization, which is a great term too, but I said civic mobilization. It's important that we hold a vision of civics that encompasses not just running a jail, but sometimes also going to jail. For this mobilization we all need to stick together. With people in the Global South, with people in minority and indigenous communities, and with people who our stereotypes might not identify to us as possible and necessary allies – people across the red versus blue line. Sarah Smarsh's book "Heartland: A Memoir of Working Hard and Being Broke in the Richest Country on Earth" powerfully tells this story.

None of this will be easy – but it is undeniably within our power to achieve a fast drawdown toward zero emissions. I'm equally convinced we need to take fast action on the slower solution of perennializing the landscape. We need to sequester carbon in the soil as a supplement and a failsafe to drawing down emissions from fossil fuel use. We know with a very high confidence that soil carbon sequestration is maximized under long-term stands of diverse, perennial vegetation, and we have some reason to believe that the very best annual systems may not be just in second place, but a distant second place. In other words, perennials are the gold standard for soil carbon sequestration – and especially perennials grown in high biodiversity.

With changes to our food system we can retire some of our current annual grain crop acreage and convert it to the perennials we already have – pasture and rangeland and grasslands and forests. But stopping there would be like proposing "some" reduction in fossil fuel usage – it's out of step with the gravity of the climate emergency. A truly serious soil carbon sequestration effort would ultimately seek to perennialize nearly all of the roughly 70 percent of our cropland currently devoted to grains, pulses, and oilseeds. A truly serious approach would be to fully develop perennial grain polycultures.

With Kernza® and perennial rice taking baby steps into production, we now have proof of concept that such a thing as a perennial grain crop is possible. As we improve our capacity and add collaborators, our work is accelerating. But even at this rate, full implementation is still decades away. The current global financial outlay for breeding perennial grain crops is, by one estimate, one tenth of one percent of the funding devoted to breeding annuals. While no level of resources would make perennial polycultures a snap-your-fingers quick fix, a higher level of funding for this evolving global research coalition could shave years off of the timeline.

That's why we need an immediate and decisive initiative from government and civil society alike to support perennialization – grass down all the annual cropland we can now, to pastures and prairie, and fully fund an aggressive global perennial polyculture grain crop research initiative. We need action from the public, philanthropic, and investment sectors alike, and we need it now. If we have really and truly learned the hard climate action lessons of the last 30 years, we know that the time to get started on necessary transformational change is always now.

But there's more at stake here than just the biogeochemical process of carbon sequestration. The larger mistakes we are making are not the mistakes of people intimately connected to the land. They are the mistakes of people swimming upstream against a culture of alienation from the land. We need to end the Age of Carbon, as Amory Lovins has said, when it comes to our energy economy. But when it comes to our culture and our agriculture, we need to restart the Age of Carbon – the Age of Organic Matter – the age of groundedness to the place where we live. Moving from an extractive relationship with "the environment" to fully assuming our duties and privileges as members of the ecosphere requires us to ask and answer a question that has sounded from The Land Institute many times: "What does nature require of us here?"

Here's an exercise. Take a one dollar bill out of your wallet. Look at the back, at the Great Seal of the United States. You'll see an unfinished pyramid topped by an all-seeing eye and the words *Annuit Coeptis* – meant to be read as "Providence Favors our Undertakings". On the bottom, *Novus Ordo Seclorum* – "New Order of the Ages". We're a modest people, we Americans. There was a first draft of this design, back in 1782. Instead of any of the text we read today, it said, *Deo Favente Perennis* – "God willing, everlasting". I kind of like the ring of that. Now, 1782 isn't so late that they had the concepts of God and nature totally separated. How about *Natura Favente Perennis*? I will submit to you that any complete response to climate change will need that ethos: "Nature willing, everlasting".

Even in this time when alarm is in the air and urgency is the order of the day – most especially in this time – our lessons start in the soil, and rise from the ground up.

One last paradox: panic versus calm. On the one hand, we cannot afford to be unstirred by this crisis. We cannot afford to indulge in mental or emotional complacency, because we cannot afford inaction. The time is short and the odds are long. As Greta Thunberg said, our house is truly on fire and we need to panic. On the other hand, we cannot afford fluttery, unfocused reactions bred of panic – they are little better than inaction, and in some cases much worse. And we can't afford paralysis or a fatalism born of impending doom, as it too results in inaction.

The answer is we need to own both our panic and our calm. The message I got from Greta is that if your house is on fire, you need to immediately drop what you're doing and harness your fight or flight reaction to take quick and effective action. The confluence of panic and calm is focus. And that is precisely what we are called to do now.

We are being told unambiguously by the best science our civilization can muster that climate change is here, and that we can expect large and increasing impacts that will result in lost and broken lives and lost and broken ecosystems. We will need to make

deliberate changes in our economic activities changes of an unprecedented size, and do it with an unprecedented speed. The transitions ahead of us will not all be easy or pleasant.

But, in a literal sense, we were born for this. Every person is a descendent of a hominid who looked across the African savanna with a watchful eye and survived. Everyone is a descendent of an early human who braved famines and floods and icy land bridges, in the process forging the most irresistible power in the history of the world, the power of community. These characteristics carry through. There are those whose ancestors stood on Lexington Green. There are those whose ancestors worked together to resist their own enslavement, or the enslavement of others. Those whose ancestors marched with Gandhi in Gujarat. Whose ancestors stood up at Selma. In Seattle. At Standing Rock. In a city council meeting in Flint. In a household with a domestic abuser. The blood in your veins is your bequest from generation after generation of people who faced the worst, turned panic into focus and anxiety into community, and prevailed. We were born for this.

And we know that if we pull this great transition off – when we pull this great transition off – we know that the qualities we needed to make the change – grounded-ness in the land and groundedness in community – are the same qualities we need to make and sustain a life truly worth living. *Natura favente, perennis*.

As a pre-teen and teenager I helped bale straw often enough on my family's farm in west-central Illinois, and a few summers I helped neighbors bale hay. I only have one personal memory of haying on our family farm – really just a four- or five-year-old's snapshot memory, of a tractor and a stacker and a particular field. But the other day my father told me a hay story that took place about 10 years earlier, and coincidentally in the same field – just south of the same farmstead that redwood got planted on. That day in the mid-1970s, my father and grandfather had hay down and were keen to get it up and out of the field. Uncle Ed happened to be working with them that day. Ed was really my grandmother's uncle, but to all generations he was Uncle Ed. He had been fully retired from his own farming for some time, but in recognition of the keenness to get that hay up, he was helping out. The baler went around the field, the rack was loaded up with small squares, unloaded, and the cycle continued. This is a hay story, so obviously the next plot point is enter storm clouds, stage west. The line of rain scudded up fast, and pretty soon sprinkles were falling. They didn't have a full hayrack yet, but went around again. Sprinkles became steady drops, and as the last bales were lifted, drops became heavy rain. Clothing getting heavy, the three men made it back to the buildings. Now, as anybody who has ever gotten caught working in the rain can attest to, the rush to finish diverts part of one's attention from the profound wetness of one's clothes and the general misery of the situation. So I like to imagine that as the tractor key went off and lungs exhaled, an observer might have seen my father and grandfather seem to shrink just a little bit. But Uncle Ed? Eighty years old and fully retired from farming? Dad says that a big grin split Uncle Ed's face, and he said, "I haven't been out like this in years".

Artist Rena Detrixhe has described a moment when wheat she raised "broke free of its symbolism" and became merely itself. I want you to break this story free of its symbolism for a minute. I want you to put on clothes that started out dusty and ended up soaking wet. I want you to chafe a little, and

your muscles to ache. Got it? Okay, now you can dry off and we'll get back to metaphor.

I just told you a folksy story about farming, because telling folksy stories is part of our code of conduct at The Land Institute. This one was my story, and I'm proud of it. But I also want to take a moment to break us from any idea that we're looking for only one story. We can extract critical lessons from the 1970s, from the 1940s, the 1840s, and 1740s – but we're not looking to reenact any of those times. We need to combine the best parts of these stories of the past with the stories of people alive now, both those with us now, and even more importantly, those who aren't with us yet. I'm proud of where I came from – but I'm even prouder of where we can all go together.

Friends, for us the rain is coming and the hay is still in the field. We've got to jump. A lot rides on our full presence and participation and resolve in this moment. May fate be so kind as to ordain that all our transition tasks will be pleasant. My gut tells me a few of them won't. Some of them are going to chafe and ache. We may get caught in the start of the rain. But if we can work with speed and skill, and above all if we can authentically work together – well, we haven't been out like this in years.

Adapted from the 2019 *Prairie Festival talk by Land Institute President Fred Iutzi. Recordings of festival presentations are on YouTube and our Web page. For compact discs call* 785-823-5376 *or write to info@landinstitute.org.*

The qualities we need for great change, groundedness in land and community, make a life worth living.

Why is farming such hard work?

A tilled field wants to be something else. Let's take that course to succession.

TIM CREWS

By replacing wild plants with crop plants, we humans increased the amount of solar energy converted by photosynthesis to food, the fuel of our activities. And before what I refer to as the fossil fuel bonanza, the most universal human activity powered by food from crops was, in fact, growing next year's food crops. Large-scale non-agricultural endeavors like building pyramids, or fighting wars, or composing operas required some social engineering, in which the farmer class of people worked extra hard and extra-long hours to produce the food energy that allowed the non-agricultural classes of people to exist without doing farm work. In fact, a dark side of pre-fossil fuel agriculture is that many societies coerced, through slavery or other subjugation, groups of others – other classes, races, and genders – to undertake the arduous work of farming so that much smaller groups could eat and do something else.

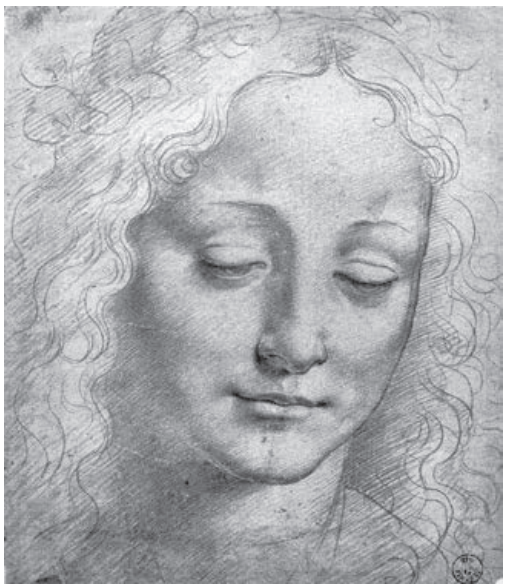
But why is farming such hard work? It seems like a silly question to ask! Because it just inherently is, right? But what are we doing that makes it so hard? Well, the activity in farming that traditionally required the most work was clearing vegetation, first by ripping out the wild perennial cover, and then weeding, and weeding, and weeding again to give the seeds and seedlings of the annual crops – wheat, barley, corn, chick pea, rice, millet, and sorghum – a chance to grow. In nature, pretty much the only time that annual plants dominate ecosystems is after a dramatic disturbance, such as a catastrophic wildfire, or a severe flood, or a landslide. The energy released by these disturbances is remarkable, and can kill the diverse and dominant native perennial vegetation that characterizes forests, grasslands, deserts, and savannahs. Humans, with our big brains, chose as our food producing ecosystem that rare ecosystem of a highly disturbed piece of ground, clear-cutting vegetation every year. So, fortified by the energy in the food we grow for ourselves and our work animals, we have committed ourselves to a lifestyle of extraordinarily hard work battling ecological succession with the plow, hoe, disc, and machete. By ecological succession I mean the strong tendency for ecosystems to grow back into a diverse, perennial vegetative community. If I dare anthropomorphize, recently plowed fields really want to be something else, like a prairie or a forest. And it takes a lot of energy to keep that from happening. This is the work – stopping succession in its tracks – that defined our agricultural existence – indeed, arguably defined us as a species – for the last 10,000 years.

That is, until about 250 years ago, at least for those in industrialized parts of the world. Then we learned to stop succession a new way. By employing fossil fuel energy in tractors we can clear-cut the landscape

down to bare soil every year without relying on food energy to guide plows and wield machetes day after day. And agriculture's chapter of the fossil fuel bonanza does not stop there. We figured out how to use fossil fuels to address virtually every other thing that limits crop growth: fertilizers (organic and inorganic), pesticides (organic and inorganic), irrigation, season extension with greenhouses and high tunnels, plastic sheets for weed prevention, and so on. Many of these energy expensive inputs are used to compensate for poor ecological functioning, because the fields have no roots for a good part of the year. Even in the Midwest, with some of the best agricultural science in the world, grain agriculture continues to leak 50 percent of the nitrogen applied to crops. We went from near zero use of fossil fuels to grow grain when the Declaration of Independence was signed, to 99.96 percent fossil fuel reliance to grow corn in Iowa today. If we are serious about de-carbonizing society, this overwhelming dependence must change.

I am cautiously optimistic that the work we are doing at The Land Institute, and that our colleagues are doing at over 50 institutions around the world, will help, and not just a little. If you create an agriculture that does not need to battle succession so hard, an agriculture that is much more like the natural system that was in place before, then it will not require nearly the energy inputs. And if you follow some other cues of natural systems, like fixing nitrogen with legumes, farming will need even less human-finnagled energy.

In the post-carbon future, it will be desirable to have an agriculture that does not require nearly as much work, whether you are someone who thinks we'll devise a bridge to renewable biofuels or solar electricity, or if you think the bottom is going to drop out of our technological society, leaving us to farm without machines. Either way, agroecosystems that function more like the rest of the earth's terrestrial ecosystems will give humanity a little more slack, a little more wiggle room to sort out living within unfamiliar limits. And converting ag land back to something that looks and functions more like the natural systems that came before also means capturing much of the soil carbon that was lost to the plow, and thus help put the brakes on climate change.



Food raised by others gave Da Vinci time and energy for art. And for the mining of coal, oil, and gas, which power modern agriculture and civilization. But farming annual grains still means constant battle – clearing ground and weeding – against nature's drive toward diverse perennials. An agriculture operating nearer that perennial state could relieve ecosystems, the ecosphere, and our labor.

Adapted from the 2019 *Prairie Festival talk by Tim Crews, The Land Institute's research director.*

Biologist Eric Cassetta studies silphium at The Land Institute. The oilseed crop is also being observed for us by volunteers from coast to coast. We'll learn how to organize a community for gathering data, and their findings could help us breed the plant for broad adaptation.

Civic science

How can lay people change plant research? How will research change them?

AUBREY STREIT KRUG

This summer The Land Institute's perennial oilseeds program and Ecosphere Studies sent silphium seedlings to more than 40 people, who are growing and tending these plants in 18 states ranging from Kansas to Wisconsin, Pennsylvania, Florida, Texas, Arizona, and Washington. Participants in this silphium civic science pilot project have tested our instructions for planting, measured the leaf lengths on their strongest and weakest plants, and described the habitats surrounding their plantings. When their silphium plants come back up again next spring, they will be able to report survival rates and start watching for buds and blooms.

Participants are helping us learn how to organize a community to gather information. Knowledge about how silphium responds to multiple growing environments – including the pollinators, pests, and pathogens in those places – may be helpful for silphium breeding in terms of broad adaptation.

Our civic science collaborators are also sharing their experiences with caring for silphium. They water, weed, and tend the plants. They send in photographs and exchange e-mails with questions and ideas. Most participants said they were checking on their silphium every day or every few days this summer and fall. During the first month of establishment, they reported seeing insects, mammals, and humans in their communities and neighborhoods interacting with their silphium plants.

In monthly surveys, we ask about their choices and reflections to understand if and how this repetitive, modest, hands-on care work shapes their learning and understanding. So far, they have answered that their experiences observing the plants and explaining the silphium project to their family and neighbors are the most helpful to maintaining their motivation and interest.

Many of these pilot project participants were already familiar with The Land Institute and were motivated to join the project because of their interests in native, pollinator-friendly plants or in perennial agriculture. A majority said they are concerned about the future availability of food and soil, and that they want to participate in scientific research and contribute to transforming agriculture.

Will their motivations *persist* over time? Will they develop emotional attachments just to their silphium plants, or to plants more broadly? Will their understanding of key concepts in ecological agriculture, such as perenniality and diversity, deepen? Will their research change their own mindsets, beyond the fate of the seedlings they care for? Will their experiences and the educational materials we provide simply help them perceive silphium as a beautiful, native perennial garden plant? Or, will they and others learn to socially and commercially

value silphium as a next generation food crop with ecological benefits? And if any of these changes in people happen, how will we know, and how will we know why?

Answering these questions involves research methods from the arts, humanities, social sciences, and natural sciences, and invites an integrated and transdisciplinary approach. Though it will be challenging, we are excited to undertake this community-based work. We are exploring how to bring more people into this effort, to generate a sufficiently robust and diverse data set for the purpose of scientific validity. Participants in our silphium civic science project tend to be white, female, and well-educated. An ethnobotanical approach, where different cultural ways of knowing and using plants become part of the connective story, may help integrate more people into this research. We need to learn if and how many regular people can improve domestication of a wild plant like silphium.

The history of domestication demonstrates how people and plants change together, and together change landscapes. For instance, this past winter The Land Institute's legume breeder, Brandon Schlautman, and I traveled to the West Bank in Palestine to visit our collaborator Omar Tesdell and the Makaneyyat research collective. We visited the cave and valley where some of the earliest evidence of human domestication of wheat was found and met some of the women farmers who continue to plant wheat and save its seeds today. We saw the effects of thousands of years of agriculture on the land and on people, the soils lost, and the struggles between societies.

How people feed themselves shapes social arrangements and cultural practices. Agriculture shapes our relationship to the larger living planet we are embedded within and the dynamic soil communities we are dependent upon. From an ecospheric perspective, agriculture is not just "out there" in fields and environments that are separate from us, but also "in here" in our bodies, in the breaths we take and metabolic processes keeping us awake, in the words, stories, norms, and values that we use to think, feel, and communicate.

This means that changing agriculture is powerful. New crops open new possibilities, both ecologically and socially. But positive change in people's behavior is not inevitable with changing plants. Our behavior, never purely individual but always in community, is both socially constructed and biologically evolved, and always shaped by our access to energy. Humans are animals who live in relationship with biophysical processes, and humans are social creatures who live in relationship to each other. Transforming agriculture requires attention to both ecology and society.

In Palestine and in our collaboration with the Makaneyyat team, we saw and continue to see what remains present: biodiversity and beauty on the landscape's hills and valleys, and creativity, curiosity, and generosity among the people. For now, there are still perennial tree crops, like olive, and knowledge of wild food plants, and spiced legumes sold as street snacks. There are still terraces holding on to soil, and in some of those hillside terraces in Mashjar Juthour arboretum outside of Ramallah, there are small research plots with potential new crops for Palestine, including perennial crops from The Land Institute. Such a persistent and dynamic food culture may help the Makaneyyat team and their collaborators build new perennial agroecosystems through community-based domestication efforts.

Here at The Land Institute, and now farther afield with our silphium civic science

community and Makaneyyat collaborators, we are pursuing persistent plant science. This work teaches us that there are truths we have to remember, and realities we have to accept, and paths we have to give up, and feelings of grief, pain, and anger that we have to experience instead of deny. And still there is the wondrous fact that we are alive now and have the opportunity to learn something completely new by doing this work for which we do not know the outcome. Maybe it is just the teacher and writer in me who is so drawn to imaginative possibility. I know that nothing is guaranteed, but isn't it astonishing, that we have the chance to be courageous?

It may be that only a just, caring, and pluralistic society that accepts ecospheric limits will sustain itself long enough to bring perennial polycultures into production. If so, then I am grateful to be part of a research community here and elsewhere who are learning to live into and embody that future society, from the ground up.

Adapted from the 2019 *Prairie Festival talk by Aubrey Streit Krug, director of The Land Institute's Ecosphere Studies.*

Land Institute research residents Eric Cassetta and Alexandra Griffin measure the varying traits of silphium.

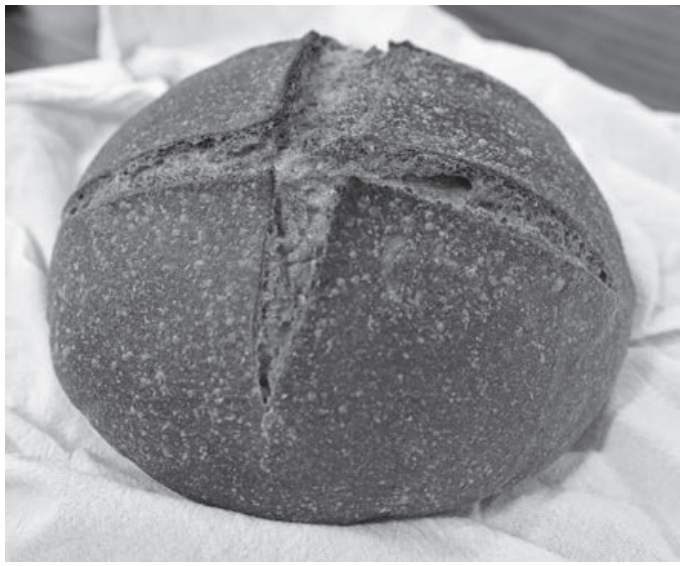
Land Report shorts

Like tofu, but sunnier

Silphium researcher David Van Tassel made a vegetable milk and tofu substitute with silphium seeds. The flavor of each was mild and suggested sunflower seed – silphium is in the sunflower family. Some batches carried some bitterness – experiments dealing with this continue. The sil-fu-yum, or faux-fu, was firm and of good texture, Van Tassel said. He has been developing the perennial silphium as an oilseed crop to take the place of annual sunflower. But using the seed for drinks and something like tofu could add value and bring food more directly to people, rather than just feeding livestock. Fare might include chai and white sauce. "It appeals to me to think about using seed this way rather than simply crushing it for oil", Van Tassel said. Most soybeans take the latter route, with the leftover solids making animal feed. Van Tassel soaked the seeds, still in their hulls, overnight. Then it was to a blender and straining through a mesh bag for nut milk. To make the sil-fu-yum, lemon juice coagulated simmering milk, with the curds going back to strain, and then overnight pressing. Van Tassel followed guides for processing sunflower seeds. For the milk, see https://bit.ly/2kwpMjJ. For the curd, see https://bit.ly/2m1Akrr. A 2004 study found the dry matter of silphium was 33.5 percent protein and 22.1 percent oil, compared with 13 percent and 24 percent respectively for domestic sunflower. Nutrition charts for firm tofu show it has about twice as much protein as fat by weight. All three seeds are low in carbohydrates.

Logging valuable wheat genes

Wheat researcher Shuwen Wang has amassed test results to register seven perennial wheat lines as "genetic stocks". This doesn't mean they are ready for commercial release, but that they have traits helpful to other breeders, and for which The Land Institute would be credited. And they might qualify as commercial varieties after testing in places with milder winters than central Kansas, where they are only weakly perennial. The valuable genes in these seven lines include resistance to a common fungal disease called stem rust, and blue seed bran,



Sourdough made with 40 percent white flour, 60 percent flour from perennial wheat in development, a resulte of crossing bread wheat with intermediate wheatgrass. Loaf and photo by Lee DeHaan.

which has been credited as an antioxidant, healthful in food. These stocks are from initially crossing bread wheat with the perennial intermediate wheatgrass. Wang is developing more strongly perennial wheat by crossing wheatgrass with durum, the pasta wheat, which has fewer chromosomes. This year he had five advanced durum-derivative lines of hundreds of thousands of plants that looked uniform in the field, a sign of genetic stability, and had consistently high seed set, seed size, and perenniality. Next year, seed from these plants will be sown at different sites around the world, to see which environment is best for each genotype.

The downs and ups of rain

A grain plant that falls over is said to have lodged. The Old French "loge", for arbor or hut, became a verb meaning to lie down. Or to get stuck. If crops fall after flowering, grain yield might be cut by more than half, according to CIMMYT, Spanish acronym for the International Maize and Wheat Improvement Center. Sunlight no longer efficiently reaches leaves. The tangled collapse covers seed heads, and the crop becomes more susceptible to pests and disease. Flattened plants are also hard to harvest.

Grain crop plants are thin and vertical. Lodging is the upset of their fine balance by strong winds, heavy rain, and wet soil. CIMMYT brought the Green Revolution in part by breeding cereal crops to grow shorter, which allowed more energy to go to making seed. They also better resisted lodging. Conventional wisdom is that taller grain plants are more likely to lodge. But that's not what appeared this year in The Land Institute's plots of intermediate wheatgrass. In central Kansas, growth of this perennial grain is limited by heat and drought. For more than a decade of development, plants grew relatively short, compared with collaborators' fields in Minnesota. But beginning last fall, Kansas weather has been wet, and lead wheatgrass researcher Lee DeHaan said the effect in his plots has been profound. Plants reached about 140 centimeters, 20 centimeters taller than usual. And with lots of rain and wind, many lodged. This gave DeHaan his first chance to sort through the strong effects of weather, and begin connecting traits in the plants with why some fell and others didn't. "We found, surprisingly, that shorter plants actually had worse lodging than taller plants, on average", he reported. "The data is a bit noisy, but still the trend is substantial, and most certainly we cannot expect selection for short plants to reduce lodging". He thinks it's probably less about height than about water loosening soil around roots and weighing on foliage. Most lodging is not buckling at mid-stem, but at the root. In fact, DeHaan also found no correlation of stem strength and lodging.

"My thought is that there is something more like wimpyness versus robustness", he said. "Wimpy plants tend to be short, weak, small seed, lower yield, etc. Big plants have the potential at least to be of the robust type. Wimpy plants have shortness as well as weak root attachment at the base of the tiller, etc. So short plants tend be sort of generally worse". CIMMYT's success with wheat came not just by finding short plants. It was by finding specific genes that limit height without downsides. "Dwarfing used in wheat is driven by a major gene with large effect", DeHaan said. "My short plants are probably just plants with lots of deleterious genes of small effect that in general give a short, weak plant". He'll investigate side-effects of selection for resistance to lodging, and whether there might be a major gene like wheat's.

Seeing through numbers

Valerie Linenberger's job as The Land Institute's new accountant is less about juggling figures than interpreting information. She studies how policies translate into financial statements. She looks for ingredients of financial strength. She keeps an eye out for spending that might be inapt and advises management about what the numbers mean.

Linenberger grew up in Salina, second of three children to factory workers, and first in her family to go to college. She would have studied English if it could have earned her a living, but she didn't want to teach. So, after doing well in high school accounting classes, she majored in economics, concentrating on accounting and management. Her minor was global studies. This was at nearby Bethany College, a small liberal arts school, which she chose over Kansas State University because "I wanted to be more than a number". She won a scholarship, but continued working 35 to 42 hours each week at Burger King, where she'd begun as a 15-year-old.

Linenberger

Linenberger served the local hospital, profit and nonprofit companies, and an accounting firm, where she prepared tax returns and audits, and helped create and dissolve businesses. She studied by herself for the CPA exam, failed, tried again, and then for six months drove to a class in Wichita before passing a test that took sixteen hours over two days and covered governmental and nonprofit accounting, business law, taxation, financial statement presentation, and auditing.

In 2016, an uncertain medical prognosis and the thought of missing out on her oldest daughter's last semester of high school led Linenberger to quit her job at the accounting firm, take stock of her life, and decide it was time for fun. She'd long been involved in fashion, and opened True Betty Boutique in downtown Salina. Its name honors an aunt whose surname was True, and a grandmother named Betty. Linenberger gives The Land Institute 32 hours each week, and after work here juggles tasks at the boutique. She also runs her own accounting and tax practice.

Linenberger likes craft classes, helping others who suffer from depression, and helping those who are autistic – her second child, Morgan, has Asperger's syndrome. Linenberger is married to Jim, whom she first dated in high school, and they have three children. Dayton, the youngest, is in middle school. The oldest, Milah, is a junior at Wichita State University, studying to be an accountant.

French & Belgian connections

Development of intermediate wheatgrass as a perennial grain crop now involves researchers in France and Belgium. ISARA, a French acronym for the Higher Education Institution of Agronomy, Food, and Environment, in Lyon, is studying how wheatgrass roots develop, the crop's effects on soil, the best soil conditions for it, how it uses water and nitrogen, the market it faces, management of its weeds and diseases, and how best to sow it, fertilize it, graze and cut it for hay, and harvest and process its grain, researcher Olivier Duchene said.

This is all to fit with ISARA's goal of farming more ecologically and sustainably. Duchene said they don't foresee wheatgrass

as being competitive strictly as a grain crop or a hay crop. They want it to serve both ends while improving soil and cutting dependence on costly additions like fertilizer and pesticides. Breeding might come by ISARA's collaborators. INRA, France's National Institute for Agronomic Research, is testing wheatgrass and perennial lines of wheat and rye. Arvalis, an applied research institute founded by and closely allied with farmers, is studying the crop's response to water and nitrogen. A French farmers co-op is helping ISARA with harvest and post-harvest work. A Belgian co-op is testing market value and post-harvest treatments. Gembloux Agro-Bio Tech, part of the University of Liege in Belgium, is running field experiments, mostly about grain-forage potential, nitrogen use, the effect of animals, and sowing methods.

Redistributing water wealth

Last year, 2018, was dry enough to stress even deep-rooted intermediate wheatgrass,

A trial in France compared effects of perennial intermediate wheatgrass, at right, with those of annual crops like the harvested wheat at left. Further wheatgrass development is happening in Belgium. Olivier Duchene photo.

our perennial grain whose food products go by the trademarked name of Kernza®. Alfalfa looked better, possibly because its thicker and deeper taproot was better at drawing from water deep in the soil. We grow the plants side by side to see if the legume can help sustain wheatgrass by sloughing nitrogen from its roots. Wheatgrass researcher Lee DeHaan noticed something after alfalfa was cut in June. The wheatgrass amid the alfalfa looked more vigorous than the wheatgrass growing alone – even fertilized wheatgrass. Perhaps water deep in the soil had moved up to the drier topsoil through alfalfa roots. Hydraulic redistribution, ecologists call this action of roots as pipeline. To explore this, intern Madeline DuBois, working with Land Institute ecologist Tim Crews, sank soil moisture sensors in solid stands of wheatgrass and in wheatgrass-alfalfa mixtures, at depths of 0.3, 1, and 3 meters. We have no results yet, because this year rain kept the soil nearly saturated from top to bottom.

On the trail at The Land

Last year, volunteers Bob Ash and Gene Sandberg began cutting a path through prairie and woods along the Smoky Hill River. They milled local Osage orange wood for benches along the trail. This spring high water collapsed steep banks of the Smoky Hill, taking downstream seven sections of trail, along with trees and two of the benches. Sandberg and Ash rebuilt, this time a little farther from the edge. All along they sought to make the trail interesting, touring tallgrass prairie, stands of bur oak, bottomland, and a cottonwood six feet thick at chest height. The result is a down-and-up hike of 2.8 miles. At The Land Institute's Prairie Festival in late September, the trail officially opened for public use. It loops through the Marty Bender Nature Area, named for our late energy scientist, on more than 200 acres a mile north of the institute office.

Sandberg had already blazed a mile-long trail at home, on land that his great-grandfather homesteaded less than a decade after Kansas became a state, and where Sandberg grew up farming wheat, oats, barley, milo, and alfalfa. Retired from more than two decades in air traffic control and air safety, Sandberg was invited to cut another path at the nature area. He brought in Ash, who recently retired from running the forestry division of Salina's Parks and Recreation Department. Both men like working outside. They first cut out small trees – no big oaks. "We wove in and out", Sandberg said. Then they pushed through a brush cutter, then a push mower. They take turns mowing the trail every week or two.

Parking and a walk-in gate for the trail are at Holmes Road and Brad Way. Dogs on leash are allowed. Bicycles and motor vehicles are not. The nature area will host education events by The Land Institute and its ecosphere studies program. For more about that and the trail, write to Carl Bowden or Aubrey Streit Krug at ecosphere@landinstitute.org, or call 785-823-5376.

Sorghum researcher wraps up

Pheonah Nabukalu came to The Land Institute in 2013 as a post-doctoral researcher, fresh from a PhD at Louisiana State University. Her job was to study the genetics behind how perennial sorghum grows. Many regular crops have been genotyped, connecting traits like seed production with molecular markers – particular DNA sequences at particular chromosome locations. But perennial sorghum comes from crossing

A public trail at The Land Institute loops almost 3 miles through prairie to the wooded Smoky Hill River and back.

two species, annual grain sorghum and a wild perennial, johnsongrass. The sequence of the result is a relative unknown. With the help of researchers at the University of Georgia, Nabukalu associated more than a thousand markers with traits that developed in the greenhouse and the field. These are traits important for improving the crop, such as flowering time, plant height, seed size, and disease resistance. They all can eventually be seen in the field. But that might take a year or more, and even then, it might not be clear what resulted from genes and what from varying fields and weather. Nabukalu cut the ambiguity over almost six years of study. With the resulting genomic map, researchers can read DNA in tissue of a mere seedling and predict its potential. Now Nabukalu will leave The Land Institute for Georgia, where her husband recently found work. She will continue to develop research papers linking the markers to field traits. This may help researchers around the world develop perennial sorghum.

So might our recent success in getting sorghum plants that produce perennial, underground stems and also have the chromosome count of established annual crop sorghum, instead of the usual doubled chromosome count of our hybrids. This will greatly ease and speed selection and breeding. Nabukalu did the microscope work to identify the simpler genomes, which sorghum research leader Stan Cox said is now the work's most important ingredient. Seed from these plants has been sent to Kenya,

Pheonah Nabukalu, at The Land Institute's Prairie Festival, helped pioneer reading genomes of perennial sorghum, and found hybrids with simpler genomes. Both achievements will speed development of the crop. Nabukalu is leaving for Georgia, but will prepare papers based on six years of research with us. Scott Seirer photo.

Uganda, and Mali, where colleagues may cross the plants easily with local, tropical crop varieties. Recipients include the International Crops Research Institute for the Semi-Arid Tropics, the largest sorghum breeder in the world.

New directors

At its September meeting The Land Institute Board of Directors elected three new members, including the first to act as the representative of institute employees: Tiffany Durr, for 15 years our greenhouse manager. The other new directors are Corey Samuels, a former intern who owns a data science consulting firm in California, and Deborah A. Neher, a University of Vermont soil ecologist.

Durr was the first female president of the Salina chapter of FFA – once called Future Farmers of America. She is dyslexic, but a seeker of silver linings, and says she uses the different wiring of her brain to find solutions – to problems beyond reading – that others don't see. She earned a bachelor's degree in horticulture from Kansas State University with the aim of landscaping, but a year later, in 2004, came to work here as greenhouse manager, fell in love with the mission, and stayed. She keeps two greenhouses running and supplied with things like truckloads of potting soil, and scouts for and manages pests. Her husband is a full-time farmer of hogs, cattle, and grain in McPherson County, south of The Land Institute. This year they planted 37 acres of one of our perennial grain crops, intermediate wheatgrass. Their two girls, 8 and 10, are in 4-H and help on the farm.

Durr

Neher developed the use of microscopic invertebrates as indicators of soil health. Her recent research includes fostering microbes in dairy cow bedding to prevent udder disease and improve milk, and designing compost to suppress crop diseases. She grew up on a farm near Quinter, Kansas, and attended her first Prairie Festival in the early 1980s, when she was an environmental science major at nearby McPherson College. She said Wes Jackson and The Land Institute inspired her career goal of using nature as a model for agriculture. She earned a master's degree in plant biology at the University of Illinois in Urbana, and a doctorate in plant pathology at the University of California in Davis. At Vermont she led the Department of Plant and Soil science for 14 years until resigning from administration in 2018 to focus on applying her research to help farmers and inform policymakers. She likes bicycling, baking, photography, gardening, and sewing.

Neher

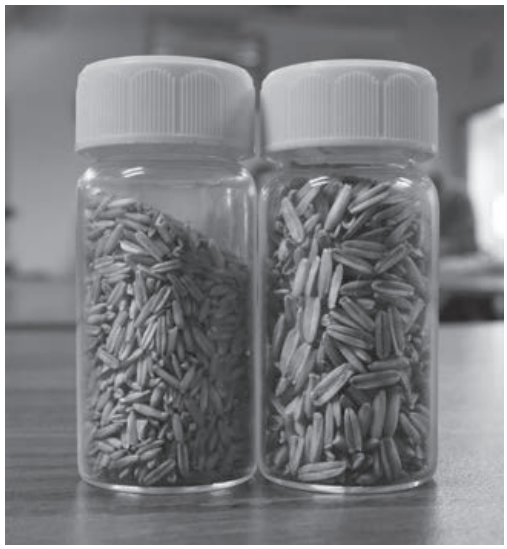
Samuels, now of Cardiff-by-the-Sea, near San Diego, grew up in Duluth, Minnesota, and Berlin. After earning a political science degree at the University of Arizona, at an ecology fair she saw a brochure about The Land Institute. "It just struck something in me", she said. She served as an intern in 1992, then became intern coordinator and interim education

director. This included helping coordinate a program in 1994 for applying complexity theory to our research. That, with its computer modeling, inspired her to a doctorate in evolutionary biology and math-rich theoretical ecology, at the University of Tennessee. She was among our first graduate school research fellows. Since college, she has applied systems thinking to fields beyond the life sciences, including space exploration and disaster relief. She developed analytics and algorithms for software, for five years led the consulting division for Wolfram, and last year founded her own firm. She helps businesses and government organizations use technology such as artificial intelligence. Her interests include writing and storytelling, and she coproduced a film called "Becoming Henry", about her grandfather, a Holocaust survivor.

Samuels

Size isn't everything

With each wild species being turned into a farm crop, we breed for bigger seed. This is partly because a bigger seed will have proportionally less fibrous coating, and more food energy in carbohydrates, and maybe in protein. Bigger seed can also bring higher yield, the amount of grain from each plant or acre. This is crucial to make perennials commercially competitive with current, annual grain crops. But bigger seed isn't the only challenge for getting bigger yield. Lee DeHaan, our lead researcher with intermediate wheatgrass, plotted seed yield per head against seed size, and found that size only explained 13 percent of the variation in yield. "It is nice that this correlation is at least slightly positive, since it makes progress for both traits simultaneously a fair bit easier and faster", he reported. A strong correlation would be faster yet. More plotting showed that 89 percent of the variation in yield per head was explained by the number of seeds in the head. This could depend on the number of florets, the sites on a head that can make seed, or on the fraction of those florets that actually do so. DeHaan found that the floret count mattered little. Two-thirds of the variation in seed yield, the biggest influence, was seed fertility. All of these relations were shown only for plants now in the program. They don't explain breeding progress over the previous decade and a half. DeHaan is exploring how populations have changed to get higher yields.



Seed from wild and improved intermediate wheatgrass. Seed size figures in yield, but there can be something more important: the proportion of florets on the head that actually fill with seed.

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Broadcasting perennials

For The Land Institute's Prairie Festival, Shuwen Wang explains wheat breeding. More than 900 people registered for the late September event. The crowd was broken into busload groups for the popular tour of research plots. In this magazine find adaptations of three festival talks: institute President Fred Iutzi on facing the challenge of climate change, Research Director Tim Crews on the tremendous energy it takes to farm – and how perennial grain mixtures would change that – and Ecosphere Studies Director Aubrey Streit Krug on how lay people across the nation are helping with research. On page 18 see news about Wang's progress with wheat.