Land Report

Number 108, Spring 2014 · 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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TO REACH US

The Land Institute
2440 E. Water Well Road, Salina, KS 67401
phone 785-823-5376
fax 785-823-8728
info@landinstitute.org

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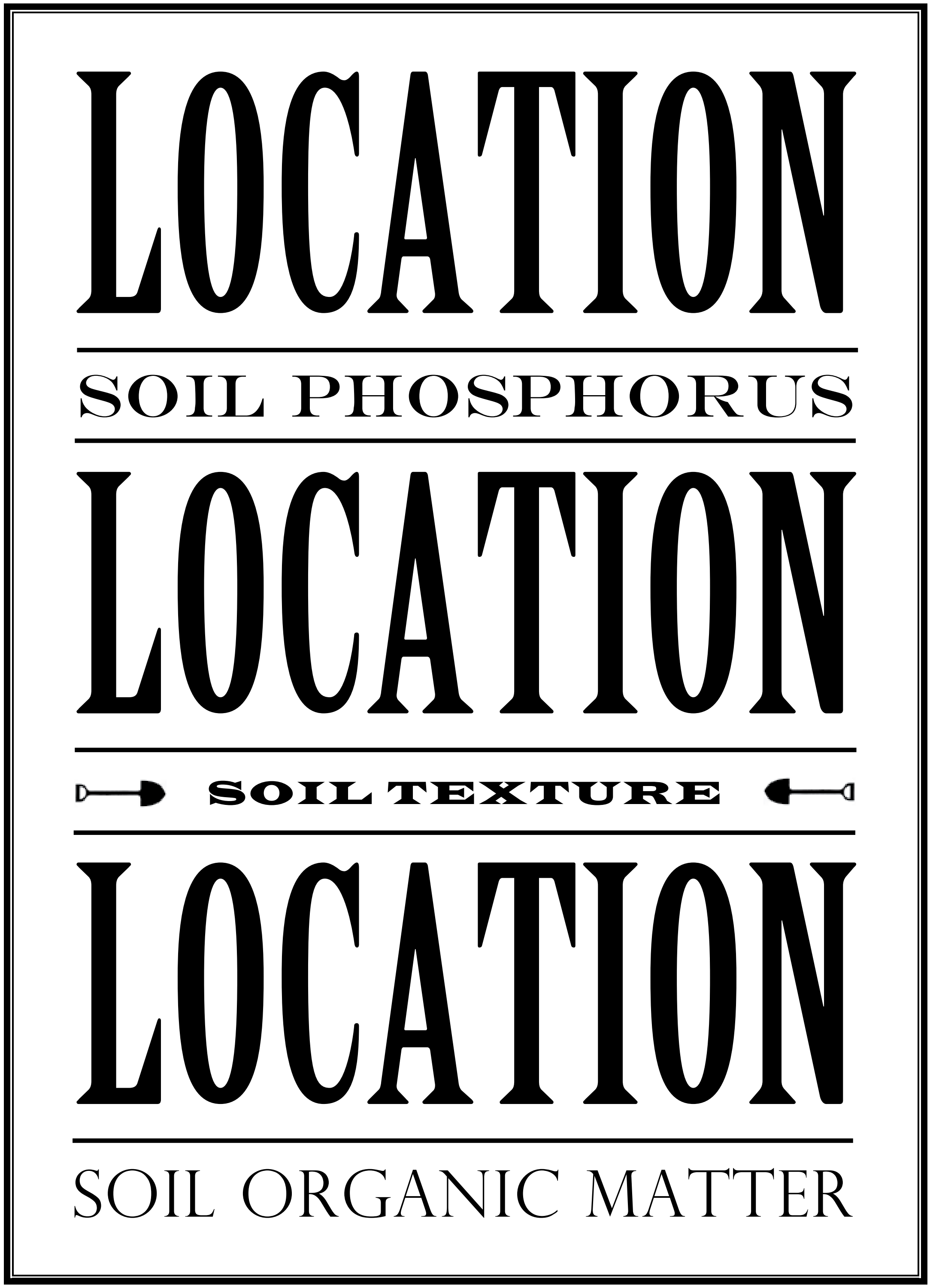
Cover

Land Institute scientist David Van Tassel ties sunflower heads together so they can be bagged. The bags collect seeds that fall from the heads, so Van Tassel can measure seed production. He also is selecting for plants that do not drop their seed before harvest time. Scott Seirer photo.



With less oil to grow and ship our food, we will refocus how we live, and maybe where. Illustration by Scott Bontz.

Will becoming local here get us there?

Few of us know if we live near a sweet spot for agriculture

TIM CREWS

We face an economic contraction inextricably tied to a ratcheting down of fossil fuel dependency. My purpose in this essay is not to support that statement. Numerous thorough and convincing texts have done so, most recently "Energy and the Wealth of Nations" by Charles Hall and Kent Klitgaard. In this essay I accept the statement, and ask whether the "local food movement" is positioning us to achieve food security as the fossil fuel based economy contracts.

The first oil well was drilled in Titusville, Pennsylvania, in 1859. I'm 51, and my life constitutes almost exactly ⅓ of the oil era. Do you know someone who is 102 or older? That person has been alive for ⅔ of the oil era. It is remarkably recent. Before the oil era began, and the coal era before it, we faced some serious limits as a species. They were limits that we can't even remember, so completely have we overcome them with fossil fuel energy. But for a low-carbon, low-growth future, I suggest that becoming local means facing some subtle contours of local limits. This is especially true in agriculture. Can you imagine an agriculture that requires little to no fossil fuel energy? A solar agriculture? I have been obsessed with this question for a good part of my life. And because synthetic nitrogen fertilizer comprises modern agriculture's greatest input of fossil energy, and because geographer Vaclav Smil says that 40% to 50% of humanity owes its existence to nitrogen fertilizers, I thought soil nutrients were a good place to delve in.

As an undergraduate and later as a graduate student, I traveled to remote parts of Mexico to find and study farming systems that had yet to adopt synthetic fertilizers. And since synthetic fertilizers are typically the first fossil-fuel based input that traditional farmers adopt, the farmers I worked with were by and large solar farmers, using no purchased inputs, no tractors, just human and animal muscle largely powered by the food grown on their farms. This is what we refer to as a "solar" agriculture. The sunlight captured by the crops through photosynthesis powers the agriculture.

Some of the farming districts I found in Mexico had been in agriculture for 2,000 years or more. So I asked, "How did these farmers maintain soil fertility for so long, and what limited their productivity?" To make a long dissertation short: all of the no-input, continuously cultivated farms I located were on relatively young soils. That's right, soils have lifespans. They are young and relatively infertile when first weathered from primary rock minerals. Minerals dissolve further and recrystallize, nutrients are liberated, organic matter forms, and soils enter a stage of high fertility. Then, over thousands of years of rain, essential nutrients leach and erode to the ocean, and soil fertility slowly declines.

All of these traditional Mexican farms that did not use fertilizers were in that young to middle-aged, high-fertility stage of soil formation. And the most important rock-derived nutrient, the one that appeared to have the greatest effect on long-term productivity, was phosphorus. You might remember phosphorus from the periodic table – it is right below nitrogen, between silicon and sulfur, and abbreviated as P. Phosphorus is in every cell of our bodies, and in those of all organisms; it is in our DNA, teeth, and especially bones. And it ultimately comes from soil weathering. Phosphorus nutrition exemplifies the intimate, clear connection our bodies have with soil, and so with glaciers, volcanoes, and other processes that lay down fresh rock on Earth's surface for soil's rejuvenation. Our existence, and that of every other organism, is tied to the weathering rate of phosphorus from rocks. That is as true today as it has been from the beginning.

After finishing my dissertation, I received an offer from Stanford ecologist Peter Vitousek to look at this soil phosphorus weathering process in Hawaii. The Hawaiian-Emperor chain of islands formed as the Pacific plate moved slowly over a hole, or hot spot, in Earth's mantel. Volcanic eruptions have created islands for millions of years in that spot, and as the Pacific plate moves northwest, the newly formed islands are carried away too. Kauai, the major island farthest northwest, is the oldest, at 4.1 million years. The Big Island, on top of the hot spot today, has volcanoes that range in age from half a million years to the present and still active.

Because of this wide range of island ages, and intense rains on the windward side, the Hawaiian Islands encompass all of the soil stages described earlier. I sampled soils in forests receiving about 150 inches of rainfall a year at 4,000-foot elevation at six sites, from a 300-year-old landscape near the Big Island volcano Kilauea, to a 4.1 million-year-old landscape on Kauai. What we found played out much as theory predicted. Little phosphorus was weathered or biologically available to plants in the young soils near the active Kilauea volcano. The amount of phosphorus cycling in the ecosystem increased with each successively older volcano we sampled on the Big Island: Mauna Loa, then Mauna Kea, and then pay dirt in the Kohalas, a 160,000-year-old volcano at the north end. Beyond that came the long decline in fertility, with the 1.4 million-year-old site on Molokai having much lower phosphorus cycling, followed by profound deficiency at the oldest site near the Alakai swamp above Waimea Canyon on Kauai.

This soil fertility gradient driven by phosphorus was, in the vernacular of field ecology, a deluxe finding. But equally deluxe was what Peter went on to do years later. He helped assemble a team of archeologists, anthropologists, soil mineralogists, paleobotanists – you name it, a sort of interdisciplinary dream team – to investigate where, among other things, Hawaiians farmed on this soil age gradient before Europeans arrived. They found that upland, rain-fed farming was remarkably restricted to the peak phosphorus soils of the Kohalas on the north end of the Big Island, and extending just across the channel to Maui. This tightly defined agricultural belt was also constrained by precipitation – to the east by too much rain, and to the west by too little. Indeed, for the upland crops that the Polynesians brought to Hawaii – sweet potato, yams and dryland taro – this was the sweet spot of soil fertility in the archipelago. And the farmers found it and farmed there, and *almost exclusively* there, in terms of upland agriculture, for hundreds of years.

So the sweet spots on the landscape that existed in Hawaiian agriculture, and the Mexican systems I studied, were significantly defined by phosphorus, and in Hawaii also by rainfall. Who knew? But other ecological factors have defined the sweet spots of other agricultural locations around the world over the last 10,000 years, including temperature, topography, and soil salinity, texture, pH, and organic matter.

OK, so you know how sometimes at the theater you are a good 15 minutes into the film before music and title appear, and at that time the movie officially starts? Well, that is what's happening now with this essay – the title of which is "Will becoming local here, get us there?"

One of the most uncontroversial social movements that cuts across a wide political spectrum is the movement to go local, and specifically in the case of food, to grow local. Even groups that traditionally back unencumbered global free trade, such as the Farm Bureau, have come out promoting local food initiatives.

A USDA report in 2010 told how local has exploded nationally over the past 20 years: Sales direct to consumer amounted to $1.2 billion in 2007, compared with $551 million in 1997. The number of farmers markets rose to 5,274 in 2009, up from about half that number in 1998. Programs supplying school meals with locally grown food increased to 2,095 in 2009, up from 400 in 2004 and 2 in the 1996-97 school year.

Locavore, local sourcing, and local food all have been championed by Land Institute Prairie Festival speakers, including Michael Pollan, Barbara Kingsolver, and Gary Paul Nabhan. So, for the record, I am not trying to convince you that buying local food is a bad idea, or that it does not matter. It does. Indeed, local economies in general deliver benefits, from retaining wealth in communities, to changing the nature of work away from a highly industrial model where labor is for exchange value rather than use value. More money spent on local food ends up in the farmer's pocket. Local food can have a smaller carbon footprint than food that is shipped long distances. And then there is the intangible joy of connecting to a specific place and soil through food. These are all huge.

But while our version of eating local makes sense now, will it get us where we need to go? Put another way, if the fossil fuel pipeline were to be cranked way down tomorrow, along with the growth economy that it now fuels, how much would the local food movement that we have today help us land back on the planet? This is where things become less clear.

Of course my title begs the question of where is here and where is there (the same question Congress is stuck on). Well, here is wherever you to live now. That is your local. Maybe you have lived there your whole life, maybe just a year, which is how long my wife, Sarah, and I have lived in Salina. Regardless, it defines your current local center of the universe. And it identifies a physical epicenter from which food that we currently refer to as local should be produced. Some say it should be grown within 100 miles. The USDA report I referred to uses 400 miles or the state you live in. The distances vary, but all agree, the closer the better.

Now let's think about why you happen to live where you do. It likely is because of a job opening, or where family lives. Many of us have made a pros and cons list when considering a move to a new place. It might include schools, temperature in January, red or blue or green or pink state, availability of local foods, bike lanes, proximity to mountains or oceans, National versus American League baseball teams, a swimming pool at the Y.

But soil phosphorus weathering, soil texture, salinity, and organic matter, the number of degree days for fruit production, actual versus potential evapotranspiration – these do not appear on the lists of the 99% of people who are not farmers, and often do not appear on the lists of farmers either. In fact, I think it is safe to say that as a whole, people have chosen where to live – in sometimes large aggregations – with no consideration of the inherent suitability of the land to sustain agricultural productivity. And yet we expect the land in a vacant lot, or just outside of town, or over the river, to provide our current population distribution all with local food. We want the food system to meet us where we are, geographically and culturally. But unlike the traditional, solar-based Hawaiian and Mexican farmers I have described, few of us know if we live near a sweet spot for agriculture, and if we do, we

Experimental intercropping of Kernza, a perennial grain, and white clover, a perennial, nitrogen-fixing legume and hay crop, at The Land Institute. This kind combination will get more out of land, water, and sunlight, with less fossil-fuel subsidy, than do annual crops under industrial agriculture. Tim Crews photo.

don't know which crops are adapted to that sweet spot, and even if we knew that, we wouldn't know how many people the landscape can feed.

In the traditional Mexican farming systems I studied, the fossil fuel share of caloric energy used to grow corn was close to zero. The energy to prepare and plant and weed and harvest the fields came from the corn and alfalfa that captured energy from sunlight in photosynthesis and went to feed the farmers and their draft animals. David Pimentel of Cornell University estimates that traditional Mexican corn-bean-squash farms like these yielded about 10 calories of food for every calorie of food metabolized by the farmer. Most indigenous or traditional agricultures without fossil fuels had ratios between 10 and 40 calories of food out per calorie of food consumed in farming. This ratio defined the amount of energy available to do everything outside farming – create art, play music, worship, fight wars, build things like the Great Wall of China. The sweeter the sweet spot found for agriculture, the higher the ratio. The lower the ratio, the less discretionary time.

The fossil fuel share of caloric energy used to grow corn in the US is 99.96%. We are truly *Homo petrolius*. In agriculture, both organic and conventional, we have figured out how to use fossil energy to address virtually every ecological limiting factor. A limiting factor is something that prevents a plant from achieving its maximum potential growth or yield, such as insect damage, weed competition, temperature, and nutrients, and too much or too little water. Phosphorus is a common limiting factor in agriculture and natural ecosystems. Its natural concentrations in the soil helped define where agriculture could take place before the fossil fuel era. Today in the US we mine phosphorus, primarily from huge pits in Florida, process it, and ship it by rail or truck to stores where farmers buy it, haul it to their farms, and apply it to their fields. A supply chain intricately tied to fossil fuels every step of the way.

The story of phosphorus in organic agriculture is not necessarily any different. You can use mined rock phosphate in certified organic production, you just can't use the acid treated version that is more accessible to plants. But most organic farmers get phosphorus by what I call dumpster diving for nutrients. They gather phosphorus-rich materials that the industrial food system sets out on the curb, in the form of manures and food wastes. In this way nutrients that originate as synthetic fertilizers commonly – not always, but very frequently – end up fertilizing local organic farms.

So in a sense, modern agriculture relies on the carbon bonds of fossil fuel slaves. I mean the equivalent work of a human that is accomplished by harnessing the energy of fossil fuels. Some may object to this use of the term slave, as it excludes important aspects of what we need to communicate about slavery, such as human exploitation and suffering. But I use it here because I worry about how interchangeable the two energy sources have been in the past, and could be in the future if we are not mindful. The adoption of fossil fuel slaves began in earnest with James Watt's steam engine patent in 1781. One hundred years later, Andrew Nikiforuk writes in "The Energy of Slaves," the output of the world's coal-fired steam engines, primarily for transportation and manufacturing, totaled 150 million horsepower. These machines collectively exerted the work of more than 3 billion humans working long shifts. The world's population at that time was 1.5 billion. So in 1880 there were at least 2 fossil fuel slaves per human, although not evenly distributed.

Now, if we take the amount of commercial energy consumed in the US today and divide it by the population, and compare this with how much energy a human expends doing physical work, the sobering conclusion is that on average each of us has 80 fossil fuel slaves working the equivalent of 10 hours a day, 365 days a year. That is 25 billion human slave equivalents, 3½ times the world population, just to maintain the lifestyle of US citizens. This conversion is not perfect, because some of the commercial energy we rely on does not come from fossil fuels. But the majority of it does. Also, some of the oil we consume is made into things like plastic bags and kayaks and drip tape, which human slave energy cannot become. But this conversion gives us a sense of how deep our dependence goes. Imagine, many if not most of us don't think twice about hopping in something that weighs 4,000 pounds, using fossil energy to move it 2 miles to buy a 12-ounce package of cheese, and then driving back. But not all of our slave force works for us as individuals, it works on the scaffolding of society and larger industrial processes that make our lifestyles possible. Like building cell phone towers, or ethanol plants, or mining phosphorus from holes in Florida.

I hope to have made clear how the effort to make landscapes grow local food is thoroughly ensconced in our fossil fuel existence. This is why we are able to grow it regardless of whether we settled in a sweet spot, regardless of how adapted the crops are to the place, and regardless of how many people want to eat local. As the fossil energy pipeline is cranked down, we will necessarily need to consider where we live, what we eat, and with how many people, much more critically. But that is only the biophysical side of the local food coin. Flip it over, and we have the cultural side, and this is where some of the most challenging and most interesting evolution will take place.

Culture is not an easy term to define, but as Wendell Berry has articulated in essays and portrayed in his fiction so well, it can be viewed as the way in which people respond collectively to living within a set of limits in a specific place. Culture develops and re-enforces behavioral norms around consumption and property, patterns of individual and collective work and leisure and expression, expectations of one's individual life in relation to the whole. All of this adds up to being able to live within the terms of a place, not as an individual but as a society. If we no longer use large amounts of dense carbon energy to make the places we live in fit our agriculture, then not only do we have to figure out an agriculture that fits the place, but we will have to adjust to it – and this will require some cultural evolution, to say the least. As fellow Land Institute researcher Stan Cox conveys in his book "Any Way you Slice It," in the face of less material wealth, and probably greater work to attain it, we will have some choices to make – to evolve our culture toward greater or lesser equality, greater or lesser exploitation.

And here's what worries me. According to Paul Gordon Lauren, who teaches international relations, diplomacy, and human rights at the University of Montana, in the year 1800, arguably the dawn of the fossil fuel era I mentioned earlier, an estimated ¾ of people were working in some form of slavery or serfdom. A majority of these people labored in agriculture. The abolition of slavery in the US coincided to a remarkable degree with the expansive adoption of fossil fuel slaves to grow manufacturing in the North. Viewed this way, the US economy has never functioned free of slaves. So we may be charting new waters in the upcoming century as some fraction of fossil fuel labor shifts back to human muscle. At least I hope they are new waters, and we don't simply figure out ways to once again exploit groups of fellow humans to pick up the work where fossil fuels leave off.

How will the work of The Land Institute change the future of local agriculture? We think it should ease the ratcheting down process both ecologically and culturally. One of the reasons many of us think fossil fuel use will decline, and with it the economy, is because of climate change mitigation. Reducing greenhouse gas sources and increasing sinks is written all over the recent Intergovernmental Panel on Climate Change summary. Agriculture is a major source of greenhouse gases now, because of land use change, loss of soil organic matter as carbon dioxide to the atmosphere, and loss of soil nitrogen as nitrous oxide. The Land Institute's perennial grain polycultures will recapture soil carbon that was lost to the atmosphere when the prairie was first plowed. Perennial crops are also predicted to emit less nitrous oxide, especially if they obtain "slow release" nitrogen from legumes.

For culture, the development of perennial polycultures should create slack in an increasingly solar-based economy that will otherwise have extremely tight margins. Put another way, an agriculture that grows much more like the natural ecosystem that it replaced will require fewer energy inputs, whether from muscle or fossil fuel. It takes a tremendous amount of ongoing work to disrupt the tendency for land in the Plains to try to become a prairie, or the land in the Northeast to become a forest. Ecosystem succession is a force of nature to contend with, and it requires huge amounts of energy to constantly disrupt it with the plow or the herbicide tank. Then it takes even more energy to substitute for the ecosystem services that got disrupted: energy to make and deliver fertilizers or truckloads of manure, to apply synthetic insecticides or natural neem oil, to weed by hand or machine.

Just think of what farmers do *not* have to do in the ideal perennial polyculture. They do not have to plow up competing vegetation and sow the crop every year, weed it, weed it again, weed it again, fertilize it with manures or synthetic nitrogen. It is entirely reasonable to expect substantial gain in the ratio of calories from food to the calories used to grow it – well above the 10-40 calories out per calorie in that solar-based farming achieved in the first 9,850 years of annual agriculture. And while this increase in agricultural productivity will not approach the force of fossil fuel slaves we currently employ to grow our food, it has the potential, if taken advantage of by a mindful society, to soften the landing back onto Planet Earth, and to reduce the tendency to seek relief from arduous and monotonous work by exploiting our fellow humans.

The challenge of rebounding from the growth economy juggernaut will reside less in the Earth's ability to meet basic human needs, and more in our ability to adjust to the limits of primarily meeting basic human needs. But an agriculture that functions like the prairie will help. It will help energetically, as I've just described, but it will also help by providing a model of how humans can integrate with ecological processes that the rest of the new local economy can follow.

So will becoming local here get us there? Well, I do not know of anywhere else to start. But I think it is going to be a little more involved than we thought. What do you think?

Adapted from a talk at The Land Institute's 2013 Prairie Festival.

Land Institute research director Tim Crews is exploring how perennial grain crops grow together, and, with measurements like this meter-deep core of earth, how they work with and affect their soil. Scott Bontz photo.

Bringing the plants together

Tim Crews explores how new, perennial grains can work as a whole

SCOTT BONTZ

In 1884 James W. Robison moved from Illinois to about 70 miles southeast of what is now The Land Institute. Robison already was an energetic, progressive, and prosperous farmer. Here he became known as "Wheat" Robison. But the plant he became first to farm in Kansas was alfalfa. A bit over a century and a quarter later, Robison's great-great-grandson, Tim Crews, left a professorship in Arizona to become The Land Institute's research director. This means he oversees breeders of the first herbaceous perennial grain crops. Crews happily drew a connection deeper than blood: "Not only is alfalfa the most impressive nitrogen-fixing forage legume, but it is also the most highly bred herbaceous perennial at this point in time." Crews is an enthusiastic man. He loves the job, and he loves its familial resonance. Sometimes human endeavor is like the rest of nature, cyclic and restorative.

Crews's own research here is in how to take his staff's grain crops and grow them in mixtures, more like prairie than modern farming's vast monocultures, and include legumes to supplant artificial, fossil-fueled nitrogen fertilizer. His research career has been in the dynamics of soils and their nutrients.

For almost 18 years he also taught and ran farms for Prescott College. The school motto is, "For the liberal arts, the environment, & social justice," and Crews is interested in more than the community of soil and plants. He said on the Prescott web site that the goal of the college food and farm programs "is not food production per se, but to nurture students with complex understandings of sustainability, who can grapple with tradeoffs at multiple scales, and ultimately move society in positive directions both ecologically and socially." The Land Institute's own mission statement is as much about society as crops. (See page 2.) Crews, whose visits here date back to his own student days, repeatedly brought Prescott undergraduates to visit and consider ideas presented at the organization's Prairie Festival and short courses.

Last year he came to stay. His daughters were leaving for college. He felt that Arizona was overpopulated. He had family roots in Kansas. He said of the institute's work, "It was the only effort I knew of where the scope of the solution even comes close to matching the scope of the problem. So we went for it."

Crews grew up in New Mexico, living first in Santa Fe and then in Albuquerque, the son of an Episcopal priest and a homemaker. He liked to toy with electricity and build things. Using his father's small greenhouse, Crews and friend Tom Sisk propagated and sold houseplants and seedling starts. They both had gardens and subscribed to Rodale's Organic Farming and Gardening magazine. Crews also joined Rodale's book

> "I still think that there is a schism between how scientists think about science and social change, and how others in society think about science and social change."
>
> *Tim Crews*

of the month club. In 1977, failing to return the refusal card, he received Wendell Berry's critique of industrial farming, "The Unsettling of America." "The next summer I read it, and it greatly expanded my worldview of agriculture and how humans relate to each other and the earth," he said. He and his friends also were interested in natural history, though Crews said he wouldn't have called it that. "More than anything, we lived to backpack, fly fish, and cross country ski."

Sisk went on to earn a doctorate at Stanford, and is now a professor of conservation biology at Northern Arizona University. Crews was attracted to alternative agriculture. The University of California at Santa Cruz drew him with a program called The Farm and Garden, and with the natural beauty of its coastal setting. "All I knew when I went to Santa Cruz is that I was interested in food production that did not degrade the people or the planet," he said. His first years of studying the liberal arts made him leery of science as a way toward social change. "I still think that there is a schism between how scientists think about science and social change, and how others in society think about science and social change," he said. "Those are big generalized groups, I realize, but there does seem to be a disconnect."

During Crews's undergraduate work, Steve Gliessman joined the university and started a program in agroecology, how food systems can follow natural ecosystems. This was part of the environmental studies program, which integrated not just natural sciences, but social sciences and the humanities. Gliessman and Ken Norris taught a class – really three courses in one – called Natural History Field Quarter. Students traveled by bus to seven ecosystems, and learned botany, zoology, and ecology hands-on. Gliessman said Crews had been inquisitive but not sure what he wanted to do. The class excited him about science. "Students get so wrapped up in it," Gliessman said. Crews followed this with Gliessman's agroecology class, read Wes Jackson's "New Roots for Agriculture," and visited The Land Institute. In summer he assisted Gliessman in a two-week study of raised-field agriculture in Tlaxcala, Mexico. Gliessman said Crews became so intrigued by the ecological foundations of the old system that he returned for a five-month study and wrote a thesis that turned out good enough for publication in a science journal. Gliessman said it was wonderful to watch Crews progress: from an interest in nature, to seeing the importance of ecology for sustainable farming, to not just learning science, but linking it to practice. (Gliessman himself edits a journal called Agroecology and Sustainable Food Systems, and runs Condor's Hope, a farm that intercrops wine grapes and olives.)

After Crews graduated from Santa Cruz, a college friend invited him to the Windstar Foundation in Old Snowmass, Colorado. He worked first as an intern and then as manager of the Biodome, a geodesic vegetable and fish farm. He met John Katzenberger, who now runs the Aspen Global Change Institute, and who encouraged him to stretch for new ideas and test them rigorously. He also met a guitarist named Sarah Hawley. Two and a half years later they married. He said, "Sarah and I got together to play music and we have been playing ever since."

The crop that his ancestor pioneered in Kansas, alfalfa, works with bacteria at its roots. In this partnership the plant feeds sugar to the microbe, and the microbe takes virtually inert nitrogen from the atmosphere and makes it part of a compound that the plant can use. But the usefulness of nitrogen isn't just about legume, microbe, and nitrogen itself. It depends other elements. Working for a doctorate under ecosystem ecologist Bob Howarth at Cornell University, Crews went back to study traditional Mexican farms that work without fertilizer. Nitrogen was the nutrient most directly limiting corn productivity. But Crews saw that regulating nitrogen's usefulness was another player, an element coming naturally from rock and soil, phosphorous.

Another, crucial, aspect of soil fertility that Crews explores is age: soils too attain and pass a prime of life. Australia's soil is ancient and poor. North America's soil is relatively young and rich. Americans don't recognize how much they owe their wealth to glaciation. Crews illustrated this kind of rise and fall with post-doctoral studies in the Hawaiian Islands, which are freshly forming at the southeast end, and 4 million years old at the northwest. (For more, see Crews's essay on page 4.)

After his work in Hawaii, Crews was well positioned to find work at a major research university. "But when a friend told me about the Prescott position, it made me reflect hard on what I wanted to achieve in life," he said. "I definitely wanted to continue with research, but for several reasons, teaching was equally attractive." One reason was that every day hundreds of research articles are published, but only a few are much read and cited by other scientists. Lesser papers consume great amounts of research energy for relatively little effect. "I wanted to have impact, and teaching seemed like it had as much or more promise than research," Crews said. "This sounds like I was ready to brainwash, which I like to think was not the case. But I knew I could help students figure out what they thought needed to be done, and instill the confidence for them to take risks." The second of his thoughts was that although science had been good at describing problems like climate change and nitrate water pollution, it had not been able to stimulate enough social change. For this Crews saw better opportunity in teaching at a liberal arts college. Lastly, Crews knew that if he were to teach, he would want to have a study farm, and to get students out of the classroom. "I reckoned that it would be easier to get research done at an innovative and flexible liberal arts school than it would be to get a major research university to agree to an innovative experiential summer curriculum in agroecology at a farm."

Over his years at Prescott College he had two farms. One was 30 acres of former desert grassland in Chino Valley, the other 20 acres of rich, alluvial soil bordered by tall cottonwoods and mesquite in Skull Valley. He also had the freedom and responsibility to design the school's agroecology program. For this he incorporated thinking from Santa Cruz and The Land Institute about agriculture and sustainability.

He also looked to native farming. "In Arizona one finds the most sustained agriculture in the US," he said. "Hopi people have been growing corn, lima beans, and other crops at the base of three mesas in northern Arizona for about 800 years with no irrigation, fertilizers, or pesticides, on 4 inches of rain in the winter and 4 in the summer." Many prehistoric agricultural peoples persisted in the Southwest for hundreds or thousands of years. "In some ways, the margins of existence are so narrow in the high desert, what is and is not sustainable becomes more apparent," Crews said. "In Kansas you can farm for decades and not know whether you are drawing down organic nutrient reserves from the soil, because the original pool is so large it is hard to see the difference. In Arizona, you know almost immediately." With irrigation, arid regions at 30-35 degrees latitude can be very productive. "If it wasn't so nice to play golf or go to school or shop in that climate, there would be plenty of water to support limited, but highly productive, agriculture in the Southwest," he said. "The problem in Arizona is overpopulation – I call it the 6 million person camping trip." He added, "There is some cognitive dissidence required in working for local agriculture when you know that it is tapping into an aquifer that is being overdrafted by 100 percent. But I guess the same holds true when I burn the carbon to fly somewhere to give a talk for The Land Institute. We are not reconciling our bills all over the place."

The most important evolution of his thinking at Prescott – and what led him to The Land Institute – probably was recognition of how far humans must go to make agriculture truly sustainable, Crews said. "I realized how even local, organic agriculture still in almost all cases requires substantial fossil fuel subsidies, still invites serious weed problems, still wastes considerable amounts of water, still leaves soil exposed to erosion, and still loses nutrients." Agriculture's problems are gaining attention around the world, but he said corrections remain far from both feeding humanity and building soil fertility, from seeing a positive energy return on investment, and from accommodating other species well enough for ecological health.

In the view of Crews and The Land Institute's Jackson, the requisite for that health would be a farming system modeled on natural ecosystems. "As far as I know, we offered the only course in Natural Systems Agriculture in the world," Crews said of Prescott. It focused much on theory: What do we hope to learn from natural systems? Can a more natural agriculture feed large populations? But students also learned hands-on at the farm. Crews led them to study wild crops, many of them used by Indians, and arrangements based on natural Southwestern plant communities. "We would work on propagating the plants, growing them in mixtures, and preparing them for eating," he said. An Earth Island Journal story about the work described pasta made from nutty, sweet flour of Indian rice grass, covered with sauce made from wolfberries and decorated with strips of prickly pear pads. There might also be a salad of amaranth and lambsquarters, a tartly sweet pink "lemonade" made from prickly pear fruit, and cookies made with mesquite flour. Crews said, "We were trying to develop an agriculture that fit northern Arizona rather than have to use fossil fuels and other inputs to make northern Arizona fit the agriculture." Students found and used plants left over from ancient Indian agriculture. Jay Bost, one of Crews's students at Chino Valley, called the experience "agroecology boot camp," with work sometimes running seven days a week, but considered its combination of theory and practice wonderful.

Crews was serious and fun at the same time, Bost said. One time the teacher told students that he had turned to his wife in bed and said, "How many people in the world, you think, woke up this morning thinking about phosphorus limitations of nitrogen fixation?" Bost credited Crews with being not only a good teacher, but for doing research in an academic environment that was not the most encouraging – a small liberal arts college, not a major land grant university. At the time Bost didn't recognize this. Now a graduate student at the University of Hawaii, he said, "In every place I study are echoes of what and with whom he has studied." Bost came to Prescott a vegan. Crews got him to think about the ethics of eating sustainably, to consider energy and nutrient cycling, and Bost decided that free-range beef made more sense than soybeans. He became what he calls a "pretty picky meat eater." He thought about this enough that when the New York Times Magazine invited essays for the ethics of carnivory, Bost found it easy. There were thousands of entries, and his won. Crews remembers seeing the piece in a readers-vote round of the competition, when authors'

Tim Crews weeds plots for studying the ecology of perennial grains. He's trying to answer many questions, such as how multiple crop species might grow together but each in a "niche," reducing competition. Scott Seirer photo.

names were concealed. He thought, Who is this guy?

Bost had left Brown University for Prescott College after meeting Crews at The Land Institute's Prairie Festival. After 2000, Crews regularly brought students to the festival and short courses at the institute, and integrated its research with his own. He challenged institute scientists on how they thought about nitrogen fixation in their picture of mixing crops like a prairie. There might be a tradeoff between high nitrogen fixation by legumes and high grain yields by grasses, he said. Rather than shrugging him off, the researchers invited Crews to participate in an annual workshop for graduate school fellows who were funded by the institute. Based on discussions there, in 2002 Crews devoted a yearlong sabbatical funded by the USDA to study how nitrogen is fixed in the soil and transferred from legumes to grasses. This was in Australia, and at The Land Institute and the Konza prairie 70 miles to the east. The year was one of extreme drought, and lack of soil moisture kept Crews from all he'd hoped to discover. But he did learn methods for measuring nitrogen transfer. "This training will pay larger dividends than I ever imagined," he said – now that he has time to focus on the questions. Crews went on to attend several Land Institute fellows workshops, and got to know the organization's researchers well. The institute agroecologist at that time, Jerry Glover, was interested in how perennials improve a soil's carbon, nitrogen, structure, and food web complexity. The two researchers' work meshed.

One difference from annuals might be in how perennials affect soil phosphorus – recall that phosphorus affects how plants can use protein-building nitrogen. A good comparison could be made in Britain. At nearly 170 years old, Rothamsted Research is the longest running agricultural research station in the world. Crews visited in 2009 for another USDA-funded sabbatical. He found that a perennial hay meadow kept phosphorus in organic pools with active microbes, while with annual wheat the phosphorus remained largely in inorganic forms, with far fewer active microbes. Crews said researchers are just beginning to understand implications of the difference. One is that the organic forms remain more accessible to plants.

Returning to Prescott after leaving the older of his two daughters to begin her studies at Hamline University in St. Paul, Minnesota, Crews again passed through Kansas and stopped at the institute. This time he was asked to think about joining the staff. Jackson had hinted at this before, when Crews felt rooted in Prescott. "But this time was different," Crews said. "I just turned 50, one of our daughters had just started college, and the other was beginning her applications. My wife Sarah felt like her work with hospice could be transplanted, and besides, Wes had shown interest in her dream of opening a green burial ground – maybe it could happen at The Land Institute. So all of a sudden there was a window, and ultimately I had to admit that I thought this was the most important work that I could contribute to on the planet." The move puts the couple closer to his parents in Minneapolis and Sarah's in Denver. A final attraction of Kansas was roots. Crews' mother was born and raised in Wichita. "But it was my great-great grandfather, J. W. Robison, who really captured my attention," he said.

Directing research for The Land Institute, Crews said he hopes to address "some of the most challenging ecological questions in perennial agriculture … and there are many!" He offered examples: How do you establish and maintain a perennial polyculture – multiple perennial crop species growing together? Is it possible to choose plants that have different enough growing habits or "niches" that they don't compete excessively? Or better yet, is it possible to choose species that actually help each other, like housing predatory or parasitic wasps that prey on pests of the sister crops, or providing nitrogen through legume-hosted nitrogen fixation? How many crop species should be grown together, and in what kind of patterns? Rows? All mixed together? Will perennial grain crops produce less greenhouse gases, such as nitrous oxide, carbon dioxide, and, in the case of rice, methane? Will they be more resilient than annual crops in the face of climate change? What happens if livestock are turned out on the perennial crops at key times? Is it possible to turn more of the perennial vegetation into food? Would the animals help liberate nutrients that would help support subsequent crop growth? How is it that for most of a century a prairie can be mowed and export in its hay the same amount of nitrogen taken during a wheat harvest, even when the wheat field receives 60 pounds of nitrogen per acre and the prairie receives none? How is it that even after fertilization the wheat field has 25 percent less soil nitrogen than the prairie?

Crews has hopes beyond his own research. He wants to develop a Land Institute program that includes researchers from regional, national, and international organizations. Now he is building a consortium of scientists from Kansas State University and University of Kansas to consider accepting graduate students from around the world to work on questions for perennial agriculture. He also seeks local change. He would like how the institute conducts its research to use less energy. Many of the scientists' trips between research plots involve hauling hand tools or paper bags. "We find it necessary to move 4,000 pounds of truck just to move the 200 pounds of body and gear," he said. On a visit last fall to a Chinese institution developing perennial rice, Crews said, "We saw some wonderful, well-built tricycles built for hauling big loads. If the load is too heavy, we also saw electric powered mini-pickup-like tricycles, which could plug into a photovoltaic array for charging."

Crews also has been thinking about The Land Institute and the future of higher education. This is only in part because of his years of teaching. "I have read many recent articles describing the inevitable decline of traditional on-campus, four-year degrees, and the equally inevitable rise of high-quality, low-cost, globally accessible online educational opportunities offered by the Stanfords and Harvards of the world," he said. "I continue to believe that education amongst interacting people in a relevant setting, like a farm, just can't be beat in terms of cultivating the whole person – you can't simply read about weeding, digging soil, or eating a Santa Rosa plum." But he also wonders if The Land Institute might have something to contribute through the Internet to students around the world.

Crews said he is at The Land Institute because human ambition needs to match the size of the problem faced, "and the work of reversing a 10,000-year gradual drawing down of the Earth's soil and ecological capital is as ambitious as it is necessary." He said, "I don't think our energy-expensive, ecologically simplified approach to growing food – even organic food – is sustainable – not in the long run. It will take more years than I have left to arrive at an ideal perennial agroecosystem, but the work going on here now is foundational, fascinating, satisfying, and remarkably hopeful."

Statue at the Chicago Board of Trade. On one side of this symbol of plenty is a bank, and on the other is a McDonald's. At places like the board and in Washington is decided farmers' futures. Scott Bontz photo.

Why don't we have sustainable agriculture now?

Perhaps farming shouldn't be left to the market's invisible hand

RICHARD A. LEVINS

Why has it been so difficult to bring about sustainable agriculture on a large scale in the United States? Or, for that matter, why don't we already have an agricultural system that would better fit most definitions of sustainable? Judging by our university efforts, we would have to answer both questions with something like "We don't yet know how to do sustainable agriculture." From this, we assume that if we did, agriculture would then become more sustainable. In response, my friends in agronomy, animal science, and related fields busy themselves developing nonchemical weed controls, cover crops, rotation schemes, and hoop houses.

A person visiting our universities might also conclude that we have made relatively little progress in sustainable agriculture because farmers don't know enough about sustainable practices. In response, we have education and outreach programs to show conventional farmers the errors in their ways. There is an implicit assumption that once farmers know more about sustainable practices, they will adopt those practices.

And, of course, my colleagues in agricultural economics will remind us that no farming system will be adopted unless the farmer finds it profitable to do so. We therefore see the occasional study that compares this or that sustainable practice to its conventional counterpart. The assumption here is that any sustainable farming systems found to be profitable will be widely adopted.

I've been observing and studying agriculture for more than a quarter century and have, at long last, come to the conclusion that none of these approaches will get us where we need to be. Surely, there is more to learn, but I think most would now agree that perennials are better than annuals, that soil erosion is bad, and that factory livestock operations have their drawbacks. Surely, there is more to teach, but most farmers could learn about sustainable agriculture if they were so inclined. And, furthermore, we now and again find a sustainable farm that is as profitable, or even more so, than those run by more conventional neighbors.

So, again I ask, "Why has it been so difficult to bring about sustainable agriculture on a large scale in the United States? Or, for that matter, why don't we already have an agricultural system that would better fit most definitions of sustainable?"

I think we would be closer to answering these questions if we face the fact that farmers no longer sit in the driver's seat of our contemporary food system. We are entirely too quick to say, for example, that we have problems with farm chemicals because farmers use them, not because farm chemical companies develop, manufacture, and promote them. Clearly, farmers are not the decision makers in poultry production and much of hog production due to contracting. Beyond that, the economic environment in which farmers work is increasingly established by agribusiness and retailers, not by farmers.

I don't like to use numbers – a strange trait for an economist, I admit – but will make a quick exception here to accentuate what I am trying to say. In 2006, the farm products grown and sold in the United States sold for $881 billion at the retail level. The farm value of those products was $164 billion. The $717 billion difference went for processing and marketing. Of the $164 billion farm value, net farm income was $59 billion, $16 billion of which came from government payments. Input suppliers and landlords, like processors and retailers, accounted for vastly more economic activity in the food system than did farmers.

Let me put it even more bluntly. Which do you think was larger in 2006, net farm income, or the cost for food packaging materials? The materials in which farm products were packaged were valued at over $10 billion more than the income of the farmers that produced those products.

So we want to change the direction of an $881 billion dollar food system, and we look to a $59 billion component of that system to make the change. This flies in the face of the principal lesson I tried to get across when I was teaching Econ 101 – "money talks."

Not only does money talk in our food system, more and more it shouts. It shouts when farm bills are discussed, when university research projects are established, and when global policies are determined. The reason is that the steady march of mergers and acquisitions throughout agribusiness and retailing have left the remaining players very powerful.

I recently heard my friend Mary Hendrickson speak at a convention. She talked about how decision making power has in large part left the farm sector. I won't embarrass myself here by trying, and failing, to do justice to her presentation of the levels of corporate concentration in our food system. Let me just say her case was convincing, and leave it at that.

Not only has decision making moved outside the farming sector, it has conformed to contemporary standards of any corporate decision making, that is, quarterly profits. I am at a complete loss to see how decision makers with a three-month planning horizon will somehow stumble on a food system that is sustainable across generations.

We implicitly acknowledge the shortcomings of unfettered corporate decision making by continuing to hope that somehow, some way, we can cook up a farm bill that leads to sustainable agriculture. We've been trying for a long time without much success, but that doesn't seem to cause anyone to give up.

I was particularly taken by the op-ed "A 50-Year Farm Bill," by Wes Jackson and Wendell Berry, in the January 5, 2009, New York Times. Its insights into what must be done were offset by a somewhat naive take on how those changes must take place: an appeal to "thoughtful farmers and consumers everywhere" ignored almost the entire decision making process in the food system. Adding that we also need a 50-year farm policy begs the question of how decisions based on quarterly profit and loss statements will ever get us one. (For a response, see page 25.)

> “What if our food system is so important that it must be regarded as a public utility?”
>
> *Richard Levins*

There is a good reason why we don’t have a 50-year farm bill, and are not likely to get one any time soon. For as long as I can remember, agribusiness has driven the farm policy agenda. John Schnittker was under-secretary of Agriculture in the 1960’s when farm deficiency payments replaced farm price supports. Many, myself included, see this as the birth of our so called “cheap food policy.” He recalled his experience in Agro Washington, winter 2007. The framework for the deficiency payments was brought forward by a Cargill lobbyist and “presented to the secretary of Agriculture and was quickly adopted.” Influence of this type is alive and well in today’s Washington. The best we can hope for are so-called “compromises” that get us nowhere.

What to do? I know economists richly deserve their claim to the “dismal science,” and so far I have laid solid claim to my share of that morbid tradition. I don’t want to end that way, however.

My longtime friend Willard Cochrane was chief agricultural economist under President Kennedy and one of the country’s greatest thinkers on farm economics. During the 1950’s, he slowly came to the conclusion that agriculture was best regarded as a public utility, something far too important to be left to the whims of a free market system. He was quickly branded a communist for saying so, and didn’t pursue the issue as much as he otherwise might have. But now is a good time to reconsider his idea.

We are looking at this very question in a different arena as I write this: banking. The nation’s private banking system has made such a mess of things that the world economy teeters on the brink of collapse. The United States is in process of doling out hundreds of billions of dollars to prop up the system. Along the way, people naturally ask: “Isn’t there an alternative to giving truckloads of cash to those who caused the problem to begin with?”

Alan Greenspan, former chairman of the Federal Reserve System, took his turn before a congressional committee and tried to explain the mess banking had become. He, unthinkably, apologized for believing that the free market system would bring us a banking system that could sustain our economy. I would have paid quite a lot to have been there!

But now we have a grand dilemma. If the market doesn’t work for banking, it makes no sense – at least to me – to pour more money into the broken system. I have heard similar discussions concerning our health care system. In both cases, we must consider fundamentally different systems for providing services.

During the 1950’s, Cochrane’s masterpiece, “Farm Prices: Myth and Reality,” made the case that the free market could not work for agriculture, either. It was more than we could take at the time, so we have tried various ways to pour money into and tack regulations onto a system that was lurching toward its own version of the banking mess – a food system that was dangerously unsustainable.

The alternative view is one that I am a bit hesitant myself to consider, but the only one that seems to take us in a direction that will result in progress. What if Cochrane was right all those years ago? What if our food system is so important that it must be regarded as a public utility? What if the free market system simply does not work for sustainable agriculture?

Many serious thinkers consider sustainable agriculture at the broad systems level, not as the occasional island of sustainable farming in an ocean of conventional agriculture. Cochrane evolved into such a thinker. In his latest book, "The Curse of American Agricultural Abundance," he outlined an ambitious plan: convert High Plains cropland back to grass and grazing operations, and transform intensive cropping areas like the Corn Belt to diversified farming.

I am not necessarily advocating Cochrane's approach here, but it does well illustrate the scale at which sustainable agriculture must be accomplished to meet important goals. At this scale, individual actions, guided by Adam Smith's invisible hand, will not likely be up to the task. In fact, we may continue to get exactly what we are getting now, that is, a food system guided by powerful players in agribusiness.

And yet, the principal means we have chosen to advance sustainable agriculture – production research, farmer education, and studies of farm-level profits – all have this in common: they assume individual action will get us where we need to be. I disagree.

As ambitious as the task of bringing about system-level change might seem, it is in some ways no less ambitious than rural electrification or building the interstate highway system. These projects did not wait for, or rely on, individual initiative, however. They were based on broad, well-focused collective action.

This brings me back to the "thoughtful farmers and consumers everywhere" that Wes Jackson and Wendell Berry appealed to in their article on farm policy. I agree that these are the people most likely to guide us toward a sustainable agriculture, but they must have decision-making power if they are to do so. We cannot pretend that they do when they are mere ants among elephants in our food system. Rather, we must contemplate an economic structure in which they have real and substantial control.

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Sorghum, a commodity crop that feeds US livestock and agribusiness, which largely controls US farming. Scott Bontz photo

Imagining political change

The 50-year farm bill was a motion that needs a second, time, and ayes

SCOTT BONTZ

Five years ago Wes Jackson and Wendell Berry proposed a 50-year farm bill. They would change the food system from one that is first about economics for production and quick profit, to one that is about ecology for sustained production through conservation. Economist Richard A. Levins is for that result. But he called the proponents naive, and said they ignored how the food system is run in Washington: by the money of corporations, not by Berry and Jackson's "thoughtful farmers and consumers." And this year's farm bill has not come around.

Jackson said he and Berry didn't expect to quickly see enacted something for which they were looking so far ahead. But he was confident of the proposal's influence. "It won't be forgotten," he said in an interview. "We have to imagine political change. We shouldn't brush aside a proposal because it doesn't have an immediate effect." He referred to the Declaration of Independence, and called each idea a kind of dare: "I dare you to take this seriously." He drew on another historic shift. Slavery's defenders asked who would otherwise do the work. So was the proposition of abolition unrealistic? "I propose the end of slavery," Jackson said. "Land slavery. Land being driven and polluted and wasted."

In his essay "Why don't we have sustainable agriculture now?" Levins suggested looking past the corporate farm bills and instead thinking along the lines advocated by a fellow University of Minnesota economist. Willard W. Cochrane saw that the inelasticity of demand for food meant farm prices would always swing wildly in a free market, and that farm subsidies meant to cushion farmers still played them to a market for ever greater production, regardless of land health. He said agriculture should be treated more like the public utilities supplying crucial water and electricity. Farmers would be guaranteed payment, but only to meet a quota, and no more.

Jackson agreed with Cochrane that historically farm policy validates and further accommodates technology to keep farmers on a costly treadmill. And he also agreed that agriculture should be treated more like a utility. Then he pointed to what stands behind the powers controlling farm policy: dense carbon energy, fossil fuels, owned and rewarded by power. We'll change the system when we rely less on dense energy, and more on contemporary sunlight, he said. Until then, "It's going to be hard to break the stranglehold." But people will quit jobs in the interest of the health of their families, Jackson said, so it's not unthinkable that farm policy can take out of the driver's seat this year's production profits and install the health of land and water. With the farm bill proposal he and Berry made a motion to do so. They called it a positive possibility for attaining a necessity.

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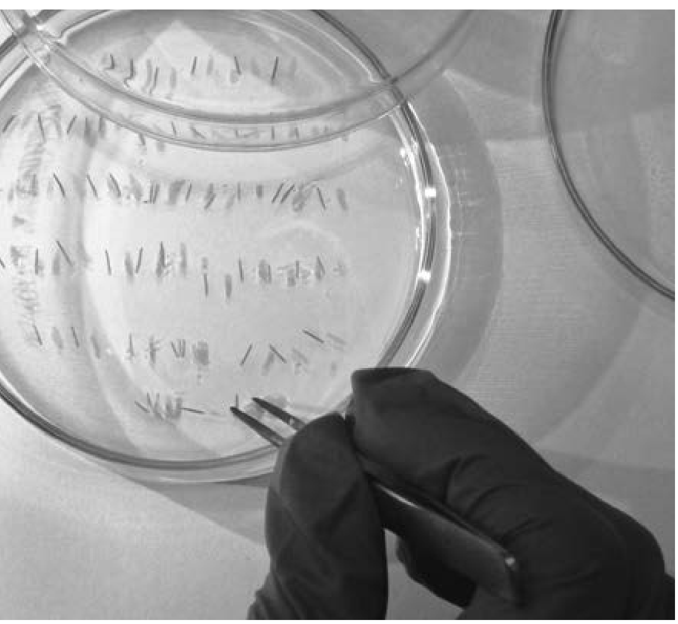

Lee DeHaan moves anthers from Kernza flowers to a growth medium. Success brings plants with half of the normal number of chromosomes, with no masking of potential traits by dominant alleles from another parent. This allows a breeder to cull unfavorable recessive alleles, and to speed inbreeding for better genotypes. Results might help not only development of the perennial Kernza as a grain crop, but in breeding with wheat to make it perennial also. Scott Bontz photo.

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Local-food agriculture frequently relies on things like plastic irrigation drip tape, potting mix, and imported manures to grow crops that otherwise don't fit. Pictured is an agroecology class at Prescott College in Arizona. For exploration of whether the local-food movement fully answers the challenge of declining fossil fuels, see page 4. Tim Crews photo.