

Land Report

Number 117, Spring 2017 · 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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ELECTRONIC MEDIA

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Kathryn Turner gathers heads of durum wheat that she has dropped from the height of 1 meter. This plant used for pasta is an annual. Hundreds of other drops by Turner and her crew are of hybrids made with annual wheat and the perennial intermediate wheatgrass. The Land Institute wants perennial wheat with heads that hold up when the plants fall into a combine header at harvest. For more about measuring and selecting for this and other traits that will make a good grain crop plant, and how Turner traces their genetic origins, see page 14. Scott Bontz photo.



Visiting scientists Alejandra Vilela and Damian Ravetta collect for analysis the heads of silphium, a plant only a few years into domestication. All our major grain crops arose without modern genetics or even record keeping, and the genetic riches of their ancestors were often lost. They are annuals, and silphium is a perennial; its domestication requires a new strategy. The Argentinians and The Land Institute have the luxury of learning the plant in a way our ancestors could not, and exercising a finer control over what to lose and what to keep. Scott Bontz photo.

Plantas Actuales

A couple in Argentina helps to tame a species without losing its wild riches

SCOTT BONTZ

For two years during his mid-twenties a Welshman named Michael D. Jones lived in his sister's adopted homeland, Ohio. By one account he saw Welsh emigrants face great hardship. By another he saw their culture quickly vanish in the melting pot. He wanted something else for them: living not only free from English ruling class oppression, but in a place entirely their own, away from the English-language culture pervading 19th century United States and Australasia. Back in Wales he mustered support for the idea, and though this nationalist, Nonconformist minister chose to make a stand at home, leading Bala Congregational College, he helped others find a fresh, isolated landscape, along the Chubut River in Argentina.

One hundred fifty-three pioneers, a third of them children, voyaged in 1865 on a ship called the *Mimosa* – the name both of a star in the Southern Cross and of a leguminous tree. Most were from cities and Welsh coal country. They claimed just a few farmers, and one man with rudimentary medical skill. Some died on the trek inland to each family's allotted 100 hectares – about three-eighths of square mile.

The new place on the steppe of Patagonia received a fraction of the rain that had fallen on lush, maritime Wales. In the first year maize and potatoes failed to both aridity and flashfloods that also took homes built from earth. With irrigation from the

Chubut, however, in two decades the area's wheat had won prizes in Chicago and Paris, and at century's end Chubut Province was an economic success. Its language for education, religion, government, and commerce was Welsh. "It looked as if the vision of a new Welsh-speaking Wales overseas would be realized," Wyn James, of Cardiff University, said recently for a BBC story about his visit to the enclave.

Then came immigrants from other cultures, and Argentina's once laissez-faire government got pushy about using Spanish. The Great War ended emigration from Wales. By mid-century in Patagonia the Celtic tongue had retreated to home and chapel.

Centenary celebration in 1965 renewed Chubut's connection with Wales, and with Argentina's government again welcoming diversity, the tie has grown. But of 500,000 people in the province, at most 1 in 100 now speak Welsh, and James said it's with a Spanish lilt. The culture is a hybrid. At the "chaining of the bard" ceremony in Wales the garb is quasi-druidic robes, while in Patagonia it is blue ponchos. And although some embrace their Welsh roots "with the zeal of a convert," most are emphatically Argentinian. Had the Welsh population of Chubut grown greater, its culture might have changed less. But in new land, climate, and political domain, an organization like ethnic culture adapts.

An organization like a crop population grown by the culture also adapts, when its farmers select, from the randomly expressed genetic palette, those traits that best work in the new place. When farmers keep and sow seed from plants making the biggest and most seed, and so over generations increase grain yields, they might also change expression of other genes. The plants could grow shorter roots. They could make thicker leaves. The change could be a tradeoff for yield, or it could be coincidence. It could make another improvement for cropping, such as less competitive roots, or it could lessen disease resistance.

Anyway, while this went on for millennia of farming before genomes could be read and mapped, traits disappeared. Between the wild organisms and the domesticated ones that we eat, there often remains no continuum, no in-between genomes and grown-out forms. Sometimes the wild thing itself is gone: the last aurochs, ancestor of modern cattle, died in 1627.

At The Land Institute, David Van Tassel is only a few years into selecting for yield from wild plants in the genus *Silphium*. He wants to make an oilseed crop like its relative the sunflower, but one that grows perennially, saving the farmer and the soil from the cost and damage of annual tillage. He has advantage over the farmers who gave us all of our significant crops even before scribes gave us writing: he draws not only on modern science, but also has for reference the wild plant, and can watch how his selection for one or a few traits affects others, including the species' crucial perennality.

Actually, combing tens of thousands of plants to improve yield, he doesn't have the time to track all of this. But other people are interested and help, including a husband and wife from Chubut Province, Argentina.

Damian Ravetta is an exuberant, athletic man. While measuring plants in The Land Institute's fields on a humid morning late last summer, for a break he went running. (And, being from a place so dry that sweat never shows, he exclaimed at the Kansas humidity.) Earlier in the year he traveled to Houston for an Ironman triathlon: 2-mile swim, 112-mile bicycle ride, and 26-mile run. His morning greetings are enthusiastic, and his farewell before a daylong journey back to Argentina includes a hug and hope to meet again.

Alejandra Vilela is lower key, but of complementary humor. She teased Ravetta for saying he wanted to travel light, with just one bag, but then taking back to Argentina a new racing bicycle. She downplays her own athleticism: not Ironwoman, just marathon runner. She also writes fiction for an annual competition. While Ravetta explained to the layman their scientific work at The Land Institute lab, she transferred to her laptop handwritten silphium numbers that filled a notebook, but she also listened, and occasionally looked over her reading glasses to fill in or add to his story.

In Trelew, Argentina, the couple runs a department of an organization called Museo Paleontologico Egidio Feruglio. The name Trelew combines the Welsh word for town, tre, and the name of Welsh pioneer Lewis Jones. The museum name commemorates an Italian-born geologist and paleontologist also honored in Ferugliotheriidae, an extinct family of tiny mammals that ran with dinosaurs of Argentina. The couple works at the fossil museum, but their operation is Plantas Actuales, "existing plants," a search for new, ecologically benign crops. Their pay comes from Argentina's National Scientific and Technical Research Council, known by the Spanish acronym CONICET. They can choose where to conduct their work, and began in

Buenos Aires, but moved to Trelew because that's where their research usually drew them, and that's the place Ravetta hails from and loves.

Seven inches of precipitation are what the plants of this land must live on. It is like the cold, high desert of Utah, and it is sheep country, with each animal needing two and half acres of scattered shrubs and grasses.

Vilela and Ravetta have studied wild plants to supply industry with resins, gums, waxes, and fibers. Soy and sunflower oil are already used in paints, but require industrial processes, in addition to destructive annual cropping. The couple seeks desert plants that make the proper oils straight up, cutting out that high-energy middle step. Using them can also preserve the ecosystem. "We don't work with annuals," Ravetta said.

He and Vilela also are developing a new theory. Most crops, including all significant grain crops, which give humanity most of its calories, were domesticated in prehistory. Those crops are annuals, which live by a different strategy than perennials. And none of them came from a place as dry as Patagonia. "There's no real theory behind what we want to domesticate," Ravetta said.

Plantas Actuales is not about plant breeding, though it has dabbled with gumweed for resin. It is mostly about basic science, with results for others to use. But it seeks plants that will be coaxed to give things such as more and bigger seed. It asks if that advance will inadvertently sacrifice drought tolerance, oil quality, or even perenniality. Most plants that make things like resins are frugal life forms in extreme environments, Ravetta said. Breeding them for productivity could backfire. So he and Vilela compare wild plants with the plants selected as improvements, to understand how they differ, and why. They also watch how different settings affect the same plant type.

By leaving Argentina's winter for a Kansas summer, Vilela and Ravetta packed two seasons of study in one year, saw silphium in another soil and climate, and sampled from tens of thousands of plants that they don't have to maintain. Van Tassel teasingly called them "data parasites."

But he will benefit. Ravetta has a device that clamps onto a leaf to measure gases. From this is calculated the rate of photosynthesis. A fungus of the genus *Puccinia* peppered the leaves of Van Tassel's silphium. Ravetta found that to a point the plant can take infestation without too much loss of photosynthesis and growth. Knowing this might influence how Van Tassel spaces his plants to slow the rust. He might not breed for complete resistance, but instead accept some disease to avoid evolution of strains that crack the established defense.

Vilela found that just a few generations of Van Tassel's selection to improve seed yield had made silphium leaves gain weight and fiber. This is an unsurprising "construction cost," she said. It isn't necessarily good. But plant breeding is a history of overcoming negative correlations.

Plants can be lumped as either acquisitive or conservative. Crop plants are acquisitive, wild plants conservative. Conservatism is associated with efficiency and stable ecology. While breeding diverts more of silphium's power to making seed, Vilela wants to see it remain mostly conservative. With the right selection and farming method, Van Tassel should get better yield while keeping silphium's perenniality and drought tolerance.

At this time it might be better to accept some tradeoffs, and select plants of different strengths – for example, for one line "yield at any price," and for a second line leaves that are highly efficient with water and light. "We can always try to hybridize

these lines, hoping we can recombine the best traits from both,” Van Tassel said. He will accept tradeoffs now because growing plants to adulthood and measuring thousands of them takes time and people, and trying to select for more than one or two traits slows progress.

He hopes to eventually know silphium’s genes well enough to confidently predict the performance of plants without having to measure every trait on every plant every year. This new way is called genomic selection. Ravetta compared it with blood testing: from a small sample you can read much about the whole body. Then Van Tas-

sel could develop models for breeding that include multiple traits. For example, an algorithm could identify plants most likely to contribute gene combinations that increase seed yield with the least risk of losing water or nitrogen efficiency.

Meanwhile, he can use a method that Vilela devised to propagate silphium with root cuttings, and so make instant communities of identical twins. This will help distinguish in the plant’s form what came from its genes, and what from the fields it grew in. From all of this will come a plant changed, but still with something like strong Welsh roots, thriving in a new kind of field.

Dreams of perennial wheat

ALEX CHAMBERS

When every morning
years in and out
you get up
to tinker
with what some call
God’s handiwork,
reaching maybe
into the soil’s gene soup –
that muddy wetness
from which almost
everything alive comes –
or scooping with a tiny
shovel the anthers’
yellow dust
into the florets
of a similar plant
whose own anthers
have been snipped off
into pollen-ready teacups,

not knowing exactly
when the roots
and the roothairs hidden
deep in the dark
and deeper will shoot
lightward, will spring up
yearly, finally,
and not only re-spring
but grow heavy,
gravid, almost, with seeds
swollen with starch,
unshatterable till
a mill
turns to powder
what the grass
no longer needs,
surplus transformed
by plant and hand
from soil to hot bread –

when your work
is attention,
a tending,
you might find
having spent your years
on a project unfinishable
in your body’s lifetime,
in that place
the plow broke once,
that the ground, finally,
as it does,
has begun
to become you.

*The writer is completing a
doctorate in American Studies
at Indiana University in
Bloomington, where he teaches
literature and politics.*

Land Institute shorts

General Mills will use Kernza

On March 7 General Mills said it would give \$500,000 for development of Kernza, and buy the perennial grain on a scale for use in its Cascadian Farm organic foods. For competitive reasons it would not specify how much will be purchased. But it also encouraged other food companies to help create a market for Kernza, The Land Institute's trademark name for products from intermediate wheatgrass. It hopes to have Kernza products on grocery shelves by early next year.

The research money goes to joint breeding work by The Land Institute and University of Minnesota. General Mills is based in the Minneapolis area. More Kernza breeding is at University of Manitoba.

Last year General Mills reported sales of \$16.6 billion. "We're looking at a company that has the capacity to produce products on a larger scale and market them on a large scale," Land Institute researcher Lee DeHaan was quoted in an Associated Press story. "That's where we see these perennial crops having to go, not just low-volume specialty producers but large-scale production that is going to be producing change in agriculture."

The fall release by Patagonia Provisions of Long Root Ale, which uses Kernza and is the first big product with a perennial grain from The Land Institute, drew inquiries from more than 140 farmers, households, and businesses. DeHaan had hoped to have a commercially viable version of Kernza by 2020. In recent years has come enough enthusiasm for the plant that DeHaan said,

"Expansion of the crop is being driven by strong demand." Grain yields and the best way to grow this perennial grain have far to go, so DeHaan cautions farmers and food companies. But he said, "Everything's ahead of our plan."

Plovgh, a Wisconsin enterprise hired by The Land Institute to help arrange a market for the crop, reported that last fall 17 farms added a total of 174 Kernza acres. Plovgh vets farms to ensure they are experienced with small-grain production and will be able to use the rest of the plant as forage, making it a dual-purpose crop. Interested buyers go on a list, so Plovgh can tell them when Kernza grain or flour becomes available. Part of the challenge – in addition to rains in the upper Midwest helping weeds and delaying planting – is giving inquirers a realistic timeline for availability of a crop still in development.

Big steps for Kernza genetics

Kansas State University researchers collaborating with The Land Institute have devised tools that will greatly help development of two perennial grains. Jared Crain is filing, on the university computer networks server, information about Kernza genetics and resulting plant forms. Institute researcher Lee DeHaan said the database will ease his genetic analysis of Kernza, a trademarked name for the perennial called intermediate wheatgrass. Kevin Dorn devised a way to match what is known of Kernza chromosomes with the genetic sequences of three



Brandon Schlautman and more than 3,700 starter pots of legumes in the greenhouse. On the facing page see more about his search for the legume species to make a perennial grain. Scott Bontz photo.

simpler species thought likely to be its ancestors. DeHaan said that knowing which *Kernza* chromosome belongs to which origin genome greatly helps in breeding not just *Kernza*, but also perennial wheat, a hybrid of *Kernza* and annual wheat.

Garden plan for lots of legumes

The Land Institute's new legume breeder, Brandon Schlautman, over winter collected seed of 144 species from 23 genera, and come spring will plant a botanical garden for a first look at perennial crop plant contenders. The garden might be arranged for Land Institute visitors to walk through. Most of the species are from North America. Schlautman also plans to plant larger blocks of 12 species already favored, and to study them for traits such as growth pattern and seed production. Each variety of each species will enjoy a tenth of an acre. For more about Schlautman and his work, see the fall 2016 Land Report.

Swedish support in Uganda

A four-year, \$650,000 program funded by the Swedish government will study how perennial grains could help small farmers in Uganda by improving soil, cutting costs, and strengthening adaptability to climate change. The perennial crops include sorghum developed at The Land Institute, plus rice and pigeon pea. The researchers are from Lund University Centre for Sustainability Studies in Sweden, Makerere University in Uganda, and The Land Institute. Lennart Olsson, a Lund geography professor and founding director of the university's Centre for Sustainability Studies, said research will enlist farmers in

two to four communities. The institute's perennial sorghum has been grown in trials in Uganda and Mali for two years already. The Swedish expansion of study began in January. Farmers, scientists, and social scientists will examine how the perennial crops and growing techniques build soil carbon, how the crops affect farmers' livelihoods, and the results for ecology and society. Land Institute researcher Pheonah Nabukalu spent February in her native Uganda to discuss with farmers how they might want to work perennial sorghum into their cropping.

Perennial wheat in China

Land Institute researchers Stan Cox and Kathryn Turner last fall met with Chinese researchers who have started testing perennial wheat, a crop that could help control erosion for the nation of more than 1.3 billion people. The Americans and Land Institute wheat researcher Shuwen Wang visited Jiangsu Academy of Agricultural Sciences, where Wang worked before coming to the United States for his doctorate. In fall 2015, Jiangsu researcher Jizhong Wu planted seeds supplied by Wang, some from his own crosses of wheat with perennial relatives, some of them from other sources. Wu was able to harvest seed, but flooding killed the plants. He plans to replant and test the new wheat for disease resistance. He also wants to study how a particular gene affects regrowth after harvest. Turner advised academy researchers on how to cut years from breeding, with genetic maps and statistics. Cox develops perennial sorghum at The Land Institute, but he previously worked with wheat. He told Chinese researchers about his technique for replicating the prehistoric hybridization that gave humankind bread wheat. This reintroduces genetic diversity,

with strengths such as disease resistance. On that topic he also submitted a paper to *The Crop Journal*, published by the Chinese Academy of Agricultural Sciences.

Chinese ecologist visits Kansas

Bo Zhu, an agronomist and soil ecologist at Yangtze University in China, studied and talked with Land Institute researchers for a week in November. Now he wants to compare annual versus perennial rice, which is being developed by a Land Institute colleague in Yunnan (see page 22), for emissions of the greenhouse gases nitrous oxide and methane.

Amid woes, best sorghum yet

Last year researcher Stan Cox's perennial sorghum plantings suffered bad weather and, along with annual grain sorghum fields across central Kansas, the long-dreaded arrival from Texas of life-sucking yellow sugar cane aphids. But he collected more than 100 plants superior in form and seed to the best perennials of previous years. These elites largely thrived, flowering before the aphid onslaught, and allowing harvest of good seed for more breeding and improvement.

Perennials inventory milestone

Land Institute collaborators in St. Louis have largely completed an inventory of herbaceous and shrubby perennial legumes that could become crop plant candidates, and to the same end have started checking the world's grass species. This mark comes a year into the three-year project. In December, Land Institute researchers traded

notes with Allison Miller's team at Missouri Botanical Garden and Saint Louis University. The growing inventory is at the garden's web site, tropicos.org; click on Projects, then Perennial Agriculture Project. For the story see the fall 2015 Land Report.

Former director Ivy Marsh dies

Ivy Marsh, who joined the Board of Directors when The Land Institute was five years old and who served for 11 years, as part of broad environmental and civic work, died January 15 in Salina. She was 88. Born Ivy B. Flora in Centropolis, Kansas, the daughter of two chiropractors, she married a man who became a dentist, Charles Marsh. They lived in Illinois and California



Marsh

before settling in Salina, where she had attended Marymount College before the University of Kansas. Dana Jackson, who with her husband at the time, Wes Jackson, founded The Land Institute in 1976, met Marsh through the League of Women

Voters. The two couples were among founders of the local Audubon Society chapter. "There were no environmental organizations in Salina," Dana Jackson said. "As Wes and Dana's vision took off, my parents got hooked on the idea," said a daughter of the Marshes, Carrie Carpenter, who now works in fund raising for the institute. Ivy Marsh helped found the Salina Human Relations Commission, and served on the Kansas Citizens' Utility Ratepayer Board and the Kansas Natural Resource Coalition board. Wes Jackson said of her joining The Land

Institute board, “I had seen her activism and strong interest in environmental policy issues,” taking notes “all the way to the margin on both sides.” He said, “I count her as the political conscience of the community.” The depth and accuracy of Marsh’s research helped defeat a lead battery recycling plant near the institute, Dana Jackson said. “When she knew she stood on good ground, she was passionate. She didn’t back down.” On condition that they not speak, Marsh won permission for the two women to attend a meeting held to convince physicians of the plant’s safety. As the doctors left, Marsh and Jackson handed them a report from the New England Journal of Medicine about the effects of lead on children.

Ecosphere studies planning

A small January gathering at The Land Institute further discussed how to teach ecosphere studies, which has seen two larger, preliminary conferences, beginning in 2015. Ecosphere studies can be considered the cultural analogue to The Land Institute’s patterning of agriculture after natural systems. It would reform our culture’s worldview, away from seeing earth as merely useable parts, and instead as a unified system. The January participants were the institute’s Wes Jackson; Aubrey Streit Krug, a doctoral candidate in English at University of Nebraska; Bill Vitek, a philosophy professor at Clarkson University in upstate New York; and Lee Wasserman, director of the Rockefeller Family Fund. Their conversation included an intellectual framework for the new way of thinking, a curriculum, and the need to deliver it quickly, both to undergraduate students and to people outside college. Vitek’s appraisal of the program included “Equal parts think tank, work camp,

classroom and refuge from the insanity of our extractive lifestyles.” The larger, third annual conference will gather at The Land Institute in June. For an argument to teach ecosphere studies before college, see page 18.

Silphium with a large head

The crew threshing more than 1,000 silphium plants found one with a seed head of more than twice the average width. “I have never seen anything like this in the past,” researcher David Van Tassel said. Getting bigger seeds and more seeds per head depends on a bigger head, which is what happened during sunflower domestication. Silphium is in the sunflower family, and like sunflower is being developed as an oilseed crop. Unlike crop sunflower, it is a perennial. The stand-out silphium plant made slightly smaller seeds, but Van Tassel hoped that genes from crossing with other plants would fix that. And unlike a solitary big-headed Maximilian sunflower plant that Van Tassel found when investigating that species as a crop, the silphium’s florets were not deformed and partially sterile: seed yield per head already ranked in the top 10 percent.

Publications and presentations

The November issue of CSA News, a magazine serving three national agricultural science organizations, featured work of The Land Institute and collaborators to develop perennial grains. Land Institute staff members made presentations in Missouri, China, Colorado, Michigan, and California. Upcoming presentations: April 11 in Flagstaff, Arizona; April 18 in San Juan, Puerto Rico; April 24 in Lawrenceville, Georgia; June 4, Galesburg, Illinois.





Whence hybrid traits?

At left, Land Institute researcher Kathryn Turner drops heads of perennial wheat from a height of 1 meter onto a concrete floor. Each head gets three drops, and Turner notes whether it breaks. Above, Sheila Cox tests whether bending snaps the heads, and

at what angle. These are two tests of many used to link traits with particular chromosomes in the hybrid, while discerning which ancestor passed them down: perennial intermediate wheatgrass or annual wheat. Over winter the seed heads of hundreds



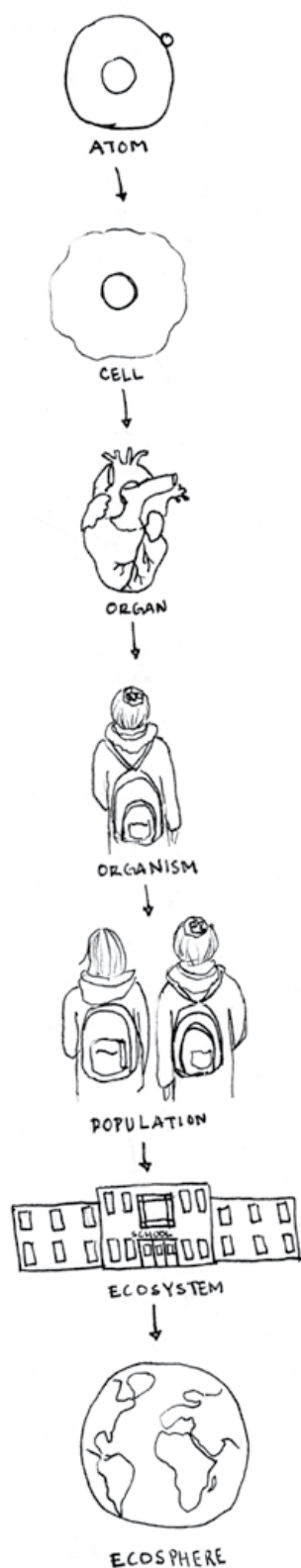
of plants went through a disassembly line to see if they broke, how they broke, if the seed threshed free from its hull, and how many seeds developed. Before this came note of traits including each perennial's regrowth after harvest, how many shoots tillered from its base, when the seed head appeared, and the head's final length. Next will come using a camera and computer to measure seed length and width. All of this goes to connecting results with chro-

mosomes and genetic sequences of wheat and wheatgrass, and that knowledge will refine and speed selecting plants to breed for perennial wheat. It matters whether a seed head breaks on impact or under bending because a combine's threshing drum is designed to work best with heads that stay intact while the machine mows down the plants and swallows them with an auger. Farmers have that cohesion with wheat, and they'll want it with wheatgrass, for the



greatest seed harvest and least waste. After dropping and bending the heads, Turner puts them through a desktop machine for threshing and winnowing. In the photo on the facing page, she gathers the freed kernels, and separates the spikelets: those that broke cleanly from the shaft called rachilla, and those that hung on. What she and the combine want are the former. Next the fragments go through a vigorous threshing that knocks loose more seed from hull. But the

first, softer treatment should be enough to find the free-threshing grain of crops like wheat. In the photo above, Sarah Hamilton weighs seed that desirably lost its hull (in right bowl) and saves the intact spikelets to investigate their relationship to seed shape. She records on a spreadsheet those masses and half a dozen other variables that Turner has noted in shorthand on the envelope. To build a new agriculture demands meticulous deconstruction. – *Text and photos by Scott Bontz.*



Where of the world to begin

Learning how everything connects need not – should not – wait until college

KATHERINE JENKINS

At the Land Institute's first ecospheric studies conference, in 2015, I was the only secondary school teacher present. I was heartened that we had so many thinkers and doers engaged in preparing the way for ecospheric studies at the university level. But why do students need to wait until college for something so critically important?

My K-12 independent is unusual in that it has for many years offered ninth grade environmental science. Many other schools in the area make biology or physics their required ninth grade science. Our course lays the foundations of basic biology, chemistry, and physics, which students continue studying in their tenth, eleventh, and twelfth grade courses. But it also explores concepts in ecology, macrobiology, population dynamics, energy source comparison, and agriculture, ideas that students are unlikely to encounter in their future science sequence unless they choose, or stumble across, them in electives. The 21st century core competencies – of critical thinking, problem solving, design thinking, collaboration, and information literacy – will certainly need to be applied to these concepts as we prepare our children. The ecological capital of our soil, water, atmosphere, and biodiversity are being diminished beyond the tipping point of supporting life as we have known it. This requires an understanding of living and non-living things beyond the scale of the atoms, molecules, ionic

Illustration by Dora Hilker.

compounds, genomes, organelles, and cells that is often so focused upon in traditional high school science courses.

Yet my department is being told to do away with ninth grade environmental science and replace it with the more common ninth grade biology. Some of this pressure comes from an eagerness to offer more upper-level electives, but much of it comes from parents and students anxious for students to be accepted into competitive STEM internships after their sophomore year. STEM stands for Science, Technology, Engineering, and Math. It aims to connect education with problem-solving for real-world scenarios. Since some of these internships require previous coursework in chemistry and biology by the end of the sophomore year, some students and their parents worry that students will fall behind in the college entrance competition if they don't qualify until after their junior year.

The interdisciplinary endeavor of STEM is innovative and exciting. My school, like many, makes the development of STEM opportunities a priority. As part of this movement, "Maker Spaces" bring to all aspects of our curriculum hands-on problem solving. My students and I have used power tools to build an aquaponics system that efficiently combines the growing of fish and leafy greens. Other STEM opportunities include various long-term projects and a lecture series with visiting scientists, engineers, and mathematicians.

However, to my mind the STEM movement has too narrow a vision. I've learned how the S in STEM has problematically stood primarily for molecular biology, biochemistry, and bioengineering. It generally does not include macrobiology – systems beyond the cell – ecology or environmental science, let alone ecospheric studies. Many graduates of premier graduate programs in the scienc-

es confess that they have come through their otherwise impressive training with little education about systems larger than the cellular. This fits with the misconception that macrobiology and ecology are the old and soft sciences of yesteryear, and that STEM and bioengineering are modern fields for the leaders of tomorrow. Many high schools reinforce this notion, tracking students by ability and field. At some, the highfliers start high school with ninth grade biology, and only students needing an extra year and slower pace start with environmental science, waiting until tenth grade for biology. My colleagues in environmental science and ecology at local universities confess that they have also felt the prejudice facing their complex fields as "soft" science.

I am all for STEM if its concept of science can be expanded to include the study of the natural world in all of its grand and minute and interconnected scales. An appreciation of the interplay of systems in our ecosphere will be necessary to grasp the problems that molecular biology and bioengineering are trying to fix. For example, understanding the nitrogen biogeochemical cycle and how it has been affected by the Haber-Bosch process of making fertilizer is just as key to food security as is understanding the engineering of transgenic crops. Now that the president of the United States and members of his cabinet have made it clear that they do not accept the evidence of climate science, it is crucial that at all levels of education we emphasize two things: supporting one's argument with evidence, and understanding the interconnectedness of living and nonliving things at all levels, from the microscopic to the global.

Our school administration has decided to change the high school sequence, from ninth grade environmental science, tenth grade biology, eleventh grade chemistry,

twelfth grade physics and electives, to ninth grade biology, tenth grade chemistry, eleventh grade physics, and twelfth grade electives. Unless we can thread the principles of environmental science, or, better yet, ecospheric studies, throughout all three years of the basic sciences curriculum, they will be encountered only by the small fraction of students who take them as electives in twelfth grade. This would be impoverished training that does not prepare for

the crises we face. The only way that I can sustain the 12- to 15-hour days that secondary school teaching requires is if the key concepts of macrobiology, ecology, population dynamics, agriculture, energy sources, and the interrelatedness of systems are woven throughout the four-year curriculum. In other words, if these concepts are simply dropped along with our ninth grade environmental science course, I won't have the required heart, soul, and grit for teaching.



Students at Friends School in Baltimore, where writer teaches, apply their understanding of the nitrogen cycle by testing ammonia, nitrite, and nitrate levels in their handmade aquaponics system. Heidi Blalock photo.

Keeping them is my great hope and stake in the ground. And it is the work of my science department over the course of this year to build that four-year science curriculum.

In addition to expanding the scope of the science taught in STEM programs, I would also like to address its troubling exclusion of the humanities. (Exceptions are some incarnations that include art, and are thus dubbed STEAM programs.) Science alone will not prepare us for the end of a fossil-fuel economy. Although gas prices have recently dipped, at some point in this century fossil fuels will no longer be abundant or cheap. This will mandate reinventing entire food, economic, social, and political systems, which have all been built on that cheap energy. When it is no longer abundant and cheap, we will not have the luxury of simply relying on new technology to help us conserve and generate new sources of energy, or on bioengineering to help us mitigate some of the worst consequences of climate change. And in addition to an appreciation and understanding of the vast, ancient systems of the natural world, we will need to entirely reimagine ourselves and our literature, our art, our whole culture. We will need a new and more nuanced understanding of human history and our place in it. As one participant in the ecospheric studies conference said, we will even need a new aesthetic of beauty to accommodate a “graceful, downward mobility” girded by a different relationship to material consumption.

So for now, while still enthusiastic about STEM programs despite their limited purview, I am casting my lot with the broader vision of teaching sustainability. Until institutions adopt an ecological worldview, I will invest my desire for a global understanding of the ecosphere into broad initiatives that embrace the sustainability

movement. While this movement has been criticized for being pat and superficial, it is at least, in its deepest sense, interdisciplinary. This year my school is applying to become a Maryland Green School. This pushes student leadership and sustainability across all grades and disciplines. In the words of the Central Maryland ecumenical retreat that I attended to inform my Quaker school’s Sustainability Council efforts, we need to envision the world beyond consumerism and the myth of endless growth; to build a sustainable, resilient, and delight-filled world within the “operating space” and natural bounds of earth’s life systems; and to bring environmental justice to all.

I am encouraged by the work of The Land Institute and its collaborators to push for the institutionalization of the ecospheric world view in higher education. But until that new concept of the ecosphere is embraced in the glories and trenches of high school teaching, I will continue holding the line for respect of, at least, the environment. Our planet does not have time to wait until our students grapple with these concepts in college and graduate school. I will do this by investing in the interdisciplinary nature of sustainability initiatives, and pushing for a wider conception of STEM, that might be better translated as SSTEAM. S for science – macro and micro understanding of all scales of the natural world. Another S for sustainability – and its implicit interdisciplinary focus including the humanities. T for technology. E for engineering. A for art. M for mathematics. Maybe if we SSTEAM on in the K-12 years of education, it will amend the soil sufficiently to nurture ecospheric studies – both in the students and institutions of higher education.

Katherine Jenkins teaches at Friends School of Baltimore. Dora Hilker is a Friends tenth-grader.



*Fengyi Hu with a long-lived and economically competitive rice called PR23, in Yunnan, China.
Photo by Erik Sacks, who researches perennial grasses at the University of Illinois.*

Perennial rice gains ground

Yielding competitively, Chinese plants enjoy expanded acreage and funding

For proving perennial rice, The Land Institute's colleague in China, Fengyi Hu, has planted more than 100 acres, and after six harvests over three years seen the plants continue to match the grain yields of annual rice. "It's the biggest field of anything I've seen in China," said Land Institute researcher Stan Cox. Research Director Tim Crews said the rice tastes quite good.

Since beginning the work Hu has secured a professorship at Yunnan University. This gives him more research freedom, which can keep perennial rice in the fore rather than as a side project. The Land Institute began funding this in 2008, reviving work that had been abandoned for lack of money by the International Rice Research Institute. Hu now wins more backing from domestic sources. The Chinese fly Land Institute scientists over each year to discuss research progress. Hu finally was able to visit Kansas in February.

He grew up on a farm, and wants perennial rice to reduce both soil erosion and rice farmers' hard fieldwork. Rice is arguably the most important food for people, providing more than 20 percent of calories consumed directly.

In the tropics annual rice can make grain again after first harvest, by ratoons that sprout from aboveground stem nodes. But the ratoons are less fresh than the original stems, and their grain yield is roughly halved. From belowground stems called rhizomes the perennial rice regrows with tis-

sue more like a new plant, and grain yields don't suffer. Unlike with many of The Land Institute's plants, the rice rhizomes don't spread, but stick near the original crown, like a bunchgrass. This might help avoid yield declines from plants crowding each other. Eventually bunching might hinder regrowth from the original crown.

Hu's plants have enjoyed paddy conditions, lacking neither water nor fertilizer. Called PR23, they come from a hybrid that was made by breeding annual crop rice with wild perennial rice. Cox said The Land Institute is encouraging Hu to improve rhizome development, for upland rice that survives without irrigation. Rhizomes store carbohydrates, so longer rhizomes could help a plant through drought. By growing deeper than the crown, they also could better protect growth points from extreme heat and cold. Increasing the number of growth points might ensure survival of some when stress kills others. And genes that increase rhizome growth might be linked to other desirable genes and traits, such as deeper roots, from a hardy perennial ancestor. This could be tested by developing lines of different rhizome numbers and lengths.

Land Institute scientists, Hu, and other researchers interested in perennial grains met in 2015 in Mali. Hu would like rice that also produces in Africa's poor, often parched soils. The wild perennial rice species used to breed PR23 is from Africa. Hu hopes with progress to see perennial rice in commercial use by the end of the decade.

Stories from Aldo's daughter

Estella Leopold tells of loving, formative times in nature at the Shack

SCOTT BONTZ

Aldo Leopold's words on looking to nature for a land ethic helped make The Land Institute. What was Leopold's influence in person, day to day, with his children? Estella B. Leopold sketches answers in "Stories from the Leopold Shack."

The book is not the kind of poetic, philosophical essay with which her father sought to find a way out of humanity ramshackling nature's elegant house – though his youngest daughter occasionally quotes his beautiful prose. And for exploring deeply what made Leopold and what he achieved, there are biographies by Curt Meine and Julianne Lutz Warren. Distinct here is a firsthand testimony from youth, for "familiarity with nature and togetherness." It is told decades later, but it began as a collection for Leopold family children, and speaks with a child's enchantment.

As a teen-ager Estella went skating on the Wisconsin River: "Then a wonderful thing happened. I looked down and beneath my feet was a muskrat, swimming below the ice. I could see him shoving himself forward with his legs, while wiggling his tail. The muskrat was moving swiftly. I was impressed that he was so competent and fast. I adjusted my speed to match his, and we moved along together over the clear ice mirror. I let out a cheer and felt a sense of delight that I could join this vigorous fellow The whole experience gave me a

feeling of being with someone on my skating tour, in the company of an able swimmer who knew where he was going. Further, it was someone who lived here, and who knew the area well, we can be sure."

The area was land that Aldo Leopold bought for \$640 in the middle of the Great Depression. And he, his wife, and five children got to know it well. The family drove from their house in Madison, where he taught at the University of Wisconsin, weekend after weekend for more than a decade. Sometimes using river debris, they turned a wrecked little barn into a second home – the "Shack," presented upper case throughout the story. In the morning they cooked sourdough pancakes in a Dutch oven outside or in an open hearth – Wisconsin winter didn't stop these trips. In the evening, by lantern light, they played guitars and sang together. Between dawn and dusk in spring and summer, they transplanted thousands of trees and prairie plants to revive 80 farmed-out acres. And they roved the place for fun and learning.

"My father had developed a craving to have his own land to experiment with a new idea: ecological restoration. We needed, he said, to find out what the original vegetation had been like in our area and what we could do to bring it back."

The myriad pine seedlings came from a nursery, but the idea's newness meant there were not yet seed services for re-

establishing prairie forbs and grasses. The Leopolds dug up mature plants from stands they deemed plentiful, often along railroad rights of way.

Estella Leopold relates a story told by her youngest brother, Carl, of when he and his father found two couples digging up Leopold pines. One of the diggers offered assurance: "Oh, we're not going to hurt them.

We are going to plant them in our front yard, and they will do fine!" Aldo pushed his hat back and said, "Well, goddamn!" The other man said, "Please, there are ladies present!" Estella writes, "Where upon Dad began to laugh and laugh and laugh. That was rare!"

She says he asked his children to figure answers to questions about what they saw



At the Shack, a tiny, decrepit barn that they made their getaway, get-to-nature home beginning in the middle 1930s, four of the seven-strong Leopold family: Aldo, his wife, Estella, daughter Estella, and son Starker. And the springer spaniel Flicky. Photo courtesy of the Aldo Leopold Foundation. To read more, see aldoleopold.org.

happening in nature around the Shack – such as why trees were bigger at one end of a river island than at the other. All five children made careers in ecology.

She also shows that the children did not feel dragged along for free labor. Nor did they mind bunking in a hut without electricity and where water was pumped by hand. They filled a perforated bucket and hollered through icy showers – while their parents laughed. Carl skipped prom so he could help plant trees. (And the girl he stood up married him.) At the Shack the Leopolds also relished exploring, fishing, and hunting with Aldo's handmade bows and arrows. One chapter covers archery, including his wife's tournament wins, and the family's thrill at bow hunting deer – that their arrows always missed seems irrelevant. Of this time in the 1930s and 1940s Estella Leopold paints a near idyll. "We had a big project going at the Shack, which would be a great deal of fun, and we all wanted to be there."

She attributes this to parents "who were the happiest married couple I ever knew," and who gave their children love and respect. She writes briefly but touchingly of a wildfire threatening their land and leading to her father's death – though she doesn't note the actual cause, a heart attack – and with two quick images she conveys her mother's grief.

She devotes a chapter to broader and more institutional restoration work continuing from what the family began at the Shack, and another chapter to how the experience infected the Leopold children with need for their own shacks, places that made nature familiar, like family itself, with the "emotional twist" of seasonally welcoming their own, local wild plants and animals.

But the fresher storytelling is from more distant spells, when young Estella could bicycle with a pet crow on the handlebars, and when the Leopolds regularly gathered to sing.

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A hybrid of Medicago sativa by Medicago arborea, one of many legumes that Brandon Schlautman is evaluating as a perennial grain crop. This spring he will plant a botanical garden of contenders. See page 11. Scott Bontz photo.