Land Report

Number 113, Fall 2015 · 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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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

Pinnate prairie coneflower planted this year at The Land Institute to consider for development as a crop plant. The institute has joined with Missouri Botanical Garden and Saint Louis University to look among the world's thousands of perennials for more candidates. See page 8. Scott Bontz photo.

Wes Jackson and supporters at the Prairie Festival. In 1976 Jackson and his wife at the time, Dana, founded The Land Institute. By its 40th anniversary next year he plans to leave the position of institute president. Jackson will be 80, but he wants to continue work for an agriculture patterned after natural ecosystems. "Of course no organization stays the way it came into being," he wrote to institute directors. But he hoped The Land Institute would stick to its mission of making people, land, and community as one, "willing to make necessary adjustments in order to get on with the job while avoiding the obsessions of the dominant culture." Scott Seirer photo.

Jackson plans to retire as president

Wes Jackson does not want to stop working toward his idea for a revolution of agriculture, with grains that are perennial rather than annual, and grown in mixtures of species like natural ecosystems to improve soil, water, farms, and even the broader culture. In that last arena he wants to advance what he calls institutionalization of an ecological worldview – seeing Earth not as an environment separate from us, something for us to use, but as a working whole of which we are a part. He wants to write more. He might occasionally still help raise money for The Land Institute. But four decades after founding the organization, he plans to hand over the reins as president.

The transition is to be made by the end of June 2016, the month of the founding anniversary and of his 80th birthday. "The stars are aligned," Scott Seirer, the institute's managing director, said at the Prairie Festival in late September. Jackson also will leave The Land Institute's 16-member Board of Directors.

Jackson has made the institute and its mission his life. The organization has grown from a budget of $6,938 to $5.3 million. It employs more than 30 people, and manages buildings, equipment, and 691 acres worth a total of $17 million. In the past two years it has essentially doubled the money going to development of perennial grains, and included collaborators on every continent but Antarctica. Jackson has long said that if you choose a job that can be finished in your lifetime, you aren't thinking big enough. Years remain before perennial grains grown in mixtures can succeed commercially. But The Land Institute's prospects have never looked so bright. The man who can see the institute from his backyard, and who can be irritated to see a plastic bag left uncollected after blowing against an institute fence, knows it will be a struggle for him to let go. He has thought much about this, and wrote to the directors, "It is my intention to avoid giving advice or direction to my successor unless asked. The next president will need the best chance to be 'presidential.'"

He encouraged the institute to still use his barns and even his home for events like the institute's annual Prairie Festival.

When Seirer announced the retirement plan to 700 festival-goers, they gave Jackson a standing ovation. Next day they stood again not just after but also before Jackson's traditional festival-closing talk.

Leading the search for a successor is a committee of three board members and two employees. Jackson is not on it. Doing the search legwork is San Francisco-based California Environmental Associates. The president will need to be creative, energetic, patient, nimble of mind, and willing to challenge the status quo, Seirer said.

Jackson said to directors, "Presidents without a vision become mere reactors to the visions of those who dwell only on the mechanics of sustaining the organization. Without a vision the job runs the president, causing the necessary energies of transcendence to falter and the spirited engagement of the intellect of those around him or her to falter as well."

Where and what we are

To take our crops from vast fields of homogeneity and isolation, and instead grow them in niched mixtures of species, might help us recognize that all of our plants and livestock, and all of the things we aren't directly eating – soil, water, air, wild species – are woven as a creative whole. This whole may be called Earth, or it may be called the ecosphere. What it should not be called, Land Institute President Wes Jackson thinks, is the environment. That word connotes something out there or surrounding us, rather than something of which we are an interdependent part. He made this argument in June at a Land Institute conference for institutionalization of an ecospheric worldview – that is, changing through education how we see ourselves in the world. After the conference, Jackson's wife, Joan, found and shared with him a poem. He thought this poem spoke to making that change in view, and he sent it to conference participants with this introduction: "I loved the way it inverts much common understanding about close relationships. I send it because inversion is part of what we are all after as we think about the differences between environment as 'out there' or 'surrounded by' rather than 'embedded within'."

A Poem of Friendship

NIKKI GIOVANNI

We are not lovers
because of the love
we make
but the love
we have

We are not friends
because of the laughs
we spend
but the tears
we save

I don't want to be near you
for the thoughts we share
but the words we never have
to speak

I will never miss you
because of what we do
but what we are
together

Giovanni is a member of the faculty at Virginia Tech. Her books include "Chasing Utopia: A Hybrid."

Silphium is a plant being developed as a perennial oilseed crop. It can be seen as not just a potential "resource," but as one part of an ecosystem, and in turn part of the supraorganism that is the ecosphere. Other parts include the water molecules that silphium taps during drought, the bacteria and fungi it trades with to enrich soil, and the insects that feed from and pollinate it. We who spread the species over the land and press its seeds for oil are another of the interdependent parts. Scott Bontz photo.

Mohammed Allawala, right, from Austin College in Texas, helps plant seedlings from the genus Ratibida to see if they could be developed as food crops. The Missouri Botanical Garden and Saint Louis University will help The Land Institute canvass the world of perennials for more prospects. Scott Bontz photo.

Are there other crop candidates?

Only a handful of perennials enjoy attention, but they number in the thousands

SCOTT BONTZ

British immigrant Henry Shaw built his fortune in frontier St. Louis, starting with hardware and cutlery, expanding to agricultural commodities, mines, furs, and real estate. He retired in 1840, age 39. With about 1,000 acres to his name, for his adopted home at the confluence of the Missouri and the Mississippi he wanted to build a public garden.

Shaw's friend George Engelmann was an immigrant from Germany, and not a businessman, but a physician. He also was one of the young country's leading botanists. Engelmann wanted to see a botanical garden like those in Europe, with a library and a herbarium for the systematic collection of plant specimens. He and other scientists persuaded Shaw to make his garden more than a park.

Today the 156-year-old Missouri Botanical Garden serves visitors with myriad plants, three cafes, and half a dozen annual celebrations, including cultural festivals, flower shows, and concert series. It also claims more than 6.5 million scientific specimens, one of the world's best botanical libraries, and the world's largest online database of plant information.

A man named Peter H. Raven led the garden for four decades, bridging into this century, and greatly expanded its research activities. He championed efforts to preserve endangered plants, and co-wrote an internationally used textbook called "Biology of Plants." Since 2010, the garden's president has been Peter Wyse Jackson, an Irish botanist who has written 14 books and helped develop the United Nations' Global Strategy for Plant Conservation.

So the garden's goals are to appreciate, preserve, and study plants, not to breed them. But for pioneering domestication of perennial grains, legumes, and oilseeds, it banks information that Allison J. Miller thinks could be powerfully helpful.

Miller is a research associate at the garden. She is also an associate professor of biology at Saint Louis University, a Jesuit school founded in 1818, and the oldest university west of the Mississippi. Miller studies plant evolutionary biology, including how gene variants are distributed and change in populations, and how these apply to crop improvement. She is particularly interested in perennial crops and their wild relatives. She has studied grape, horseradish, pecan, big bluestem, and kudzu.

Allison J. Miller

Miller first met Land Institute scientists in Rome in 2013, at a United Nations Food and Agriculture Organization conference to explore perennial grains. Domesticated annual grains now supply two-thirds of human food calories. Their cultivation causes the loss of millions of tons of soil each year, and damage such as groundwater pollution by wasted fertilizer. If perennial grains were grown in mixtures of species somewhat like prairie or forest, they could vastly surpass annuals in conserving soil and nutrients.

Filling the world's diverse wild places are plant species numbering in the hundreds of thousands. The most economically important crop plants amount to only a handful or two of species, and the annuals among them command most of the world's cultivated land. Perennials being developed as an alternative to annual grains are fewer yet: Land Institute scientists guide wheat, intermediate wheatgrass, sorghum, and a few plants from Asteraceae, the sunflower family. Colleagues in China and Sweden pursue perennial rice and barley. Miller wondered about plumbing the deep well of wild perennials and testing the best species as additional candidates for agriculture.

Over the past several decades, taxonomists have amassed large checklists of the world's plants. The lists are kept at gardens and natural history museums like Missouri and London's Kew. Already tallied are about 11,000 grasses, 20,000 legumes, and 23,000 Asteraceae. These are the three plant families that produce most of the seeds used as food for humans. About 40 percent of domesticated species are perennial, but none of today's major grain crops. Close to 60 percent of flowering plants might be perennial. In the tropics it is about 80 percent. For many plants, including sorghum and tomato, being perennial or annual is not black or white. How the plant behaves depends on climate. "We'll do our best to identify where species fall on that continuum," Miller said.

Land Institute scientists had thought before about expanding the search for perennials to domesticate. The plan gelled in meetings that brought Miller together with institute President Wes Jackson. The first after Rome was at the US Botanic Garden, where participants discussed how to improve in the public eye something that might seem obvious, but which has been found lacking: the connection of plants and agriculture. The two scientists met again last November, after The Land Institute teamed with the Malone Family Land Preservation Foundation to dramatically boost spending for perennial-grain research.

Now Miller has funding from her school, the garden, and Malone to begin a program for the "global inventory and systematic evaluation of perennial grain, legume, and oilseed species for pre-breeding and domestication." Miller, Land Institute scientists, and botanists from the garden will use the project not just to find perennials with promise as new food crops, but also to study how perennials compare with annuals under the pressure of selection for crop traits. This might identify principles vital to domestication of perennials.

The project is funded for three years. This is not long enough to find and evaluate every perennial prospect, but few grants are for more than that span. "I think you have to look at this as the first stage of a 20-year project," Land Institute sunflower scientist David Van Tassel said. "I think you need to look at some of this as proof of concept." Miller put it this way: "This is a three-year project, but it's not a three-year project." The work is new, and as the scientists learn and gather information, priorities might change. Knowledge gained can attract more scientists and power more research.

The Russian scientist Nikolai Vavilov traveled the world during the early 20th century to find where crops originated, and to gather diverse seed for breeding that would improve Soviet agriculture. He focused on traditional crops – annual grains. Now the job is to find perennials. Some might be closely related to existing crops, others might not.

At least to begin the new inventory, there need be no globetrotting. Miller wants to mine literature, databases, herbaria, and living collections. She has an undergraduate student making a trial of technique with one genus, a master's degree student identifying leguminous candidates, and has hired a post-doctoral researcher who will help manage the three-year study. The team will gather information on the perenniality of species, their form, and where they grow. The scientists will collect seed from the most promising and develop long-term selection experiments. Two of the garden's ethnobotanists, scientists of traditional plant culture, will contribute information on how people already use the candidate species, and two ecologists will help test germination of collected seed.

The filter for what Miller called this "broad but shallow first pass" will answer these kinds of questions: Is the plant perennial? Is it a grass, legume, or maker of oily seed like sunflower or flax? Is it herbaceous or shrubby, instead of outright woody like a tree? (Trees take years to reproduce, and have been domesticated with transplanted shoots, grafting, and clones, not with the annual or even more frequent breeding that can transform a grass into a grain crop.) This first screening will produce a global checklist of possible candidate plants. Publication will present the names to interested crop scientists.

Next, the researchers will cull their way to a short list of contenders by evaluating the traits of each species: How much seed does the plant produce? How much and what kind of oil and protein are in the seed? Where does the plant range? Can it grow where there is need? Can it grow with other species? How easily can it be found and gathered? Is it easy to grow? How does it adapt to different surroundings? Has it been used for food before? (In an American Journal of Botany article, Miller and other scientists noted that about 10 percent of known plants are edible, and about 7,000 have been cultivated for food.) How does it reproduce? Does it survive freezing? How large and what shape are its flowers, which plant breeders will have to work with? How does it germinate? How will it handle harvest and being made into food?

Miller is not a plant breeder, and development of criteria for judging will enlist Land Institute scientists. The plants picked should be the ones that are easiest to work with, and that have desirable traits beyond grain or oil yield, Van Tassel said. For examples he gave The Land Institute's intermediate wheatgrass, which from the start made tasty and workable flour, and food products from which now have a trade name, Kernza®. There is also Asteraceae's silphium, which, in addition to bearing big seed, can withstand drought.

The Land Institute's initial inventory and evaluation of plants for domestication three decades ago passed over wheatgrass and silphium, and none of the handful of species selected then enjoy the main attention from breeders now. Eastern gamagrass was attractive as a close relative to maize, but its seed would be tough to make into grain. Perennial giant wild rye reportedly was eaten by Vikings, and was favored over wheatgrass, but it proved to make few seeds.

Meanwhile, Peggy Wagoner at the Rodale Institute evaluated candidates for perennial grain and settled on intermediate

David Van Tassel tosses from the field bagged seed heads of a promising silphium plant. By such selection he quickly improved the wild perennial's seed production. He would not stick with a species that responded slowly. In this work even a relatively speedy transformation can consume a scientist's career. Scott Bontz photo.

wheatgrass. "Peggy made a better choice than I did," Jackson said. Rodale sent improved wheatgrass for The Land Institute to use in studies crossing perennials with annual crop wheat to make perennial wheat, and scientist Lee DeHaan recognized, by how quickly selection improved wheatgrass, that he had a perennial grain candidate in its own right.

Likewise, silphium originally did not produce many seeds, though they were relatively large. Selection by Van Tassel rapidly improved production. He said that if not for that speedy response, silphium should have been left to the wild.

"There's sort of a scorecard that you might imagine for each species," he said. The more good features a plant has, the less work they will require. With enough time and attention, probably any plant can be domesticated. The challenge is to find those that can be domesticated with relative ease and speed, and which would be most marketable.

For that search, Van Tassel argued, it is not enough to look at a row of 20 plants and judge a species by the average performance. Instead, across the variation in 50 times that many plants, seek the best. He grew thousands of perennial sunflowers, which normally have multiple branches, each bearing small heads, and found just one plant that flowered on a single stalk, like annual crop sunflower. From this individual came a breeding population.

Looking at herbarium books and spreadsheets one sees averages, or at best, ranges. Van Tassel is curious to also seek opinions from those who breed forage crops, ornamental plants, and prairie restoration varieties. These are people who have with their select plant species a deep familiarity. "There is some sort of holistic gestalt about a plant," he said. Asking for this kind of appraisal might sound soft, and its methods hard to scientifically explain. At other times he has opposed it. "But in this case, I'm on the other side."

Miller said that measures indicating domestication ease – how perennials flower, whether they self-fertilize or outcross, how many chromosomes they have, their seed size – are in the literature available at the garden. To fill holes, researchers will look at plants in the wild, and request seeds from seed banks and the US Department of Agriculture. "It's hard to imagine a better place," she said of the garden and its connections. "If it's known, we'll be able to get it."

Jackson said the effort would far surpass the scope of what The Land Institute initially attempted. "This is global," he said. But though there might be 50,000 herbaceous perennial species, Miller said survey of that number at this stage would be unrealistic. "There's a limit to what we can do as information and seed gatherers," she said. "All we can do is accumulate in an organized manner." Her team will start with species and genera closely related to domesticates. "I say we're casting a wide net, but to get off the ground we'll start with subsets of groups."

Discussion with Land Institute scientists about how to whittle the initial list, and how far, continues. Miller now has in mind arriving at a short list of 100 species, which she called "the tip of a taxonomic iceberg."

After scientists have this in their grasp, there will begin collection of seed, germination trials in St. Louis, and shipment of seed to The Land Institute for growing out and study. Characteristics that could not be seen in the first pass will then appear. This is the stage called pre-breeding, when scientists know that many of their crosses will lead nowhere, DeHaan said. In breeding of plants already domesticated, the field is more refined, and the progress more incremental. Meanwhile, the botanical garden, which each year hosts about 1 million visitors, will use the candidates to make a display garden of "artificial prairie."

Experiments at The Land Institute can begin even before the final short list arrives from St. Louis, Van Tassel said. The scientists already know some candidates to test. This year he oversaw planting of two coneflowers, *Ratibida columnifera* and *R. pinnata* (see cover photo).

The program will not only seek to decide which species to domesticate, but to understand in general and with practical applications how perennials evolve as they are domesticated, and how their change compares with that of annuals. An annual has no second chance, and must give its all to make seed in one year, while a perennial is a long-term planner. And although a perennial continues to grow and yield seed year after year, it changes not only in size, but also biologically, DeHaan said.

These differences might affect how populations respond when a scientist selects and breeds favored individuals. "Relative to annuals, we don't know much about how perennial herbaceous plants respond to domestication," Miller said. They might respond in some ways like herbaceous annuals, in others more like woody perennials. Land Institute scientists have learned from their handful of herbaceous perennials, but each researcher has been out to improve a particular species, not to formally develop and test a theory.

Even how annual crops respond to domestication is not well understood, at least genetically, DeHaan said. The domestication of annuals is now rare. Most plant taming came before science. A few novel crops, such as kiwi fruit, have been recently developed. But Jackson said, "The last time that humans added a major crop to the food inventory was 3,500 years ago." Stories of how the grain crops came to be are written by archaeology and forensics. "We don't have very strong support for any of the ideas," DeHaan said. "We're not watching what happened. We're guessing."

Among other issues that suggest domestication of perennials will pose new challenges is the kind of genetic diversity that comes when a plant must have another plant at hand to reproduce. Most perennials are such out-crossers, while most annual crop plants can self-fertilize. Self-fertilization is an extreme form of inbreeding, with the unfit versions of genes quickly revealed, and their carriers culled. With out-crossers, inferior genetic variants from one parent can remain in a population if the other parent contributes a fitter version that is dominant. Although diversity is often a good thing, this kind cannot be afforded for a crop plant, whose populations must perform consistently.

Another theoretical issue for breeding of perennial grain crops is the tradeoff between making seeds for grain and making tissue such as roots so the plant can survive winter. Critics have said extra energy going to roots will keep perennials from matching annuals in seed yield. Land Institute scientists have made the case that not beginning each year from seed gives the perennial a head start. Some perennial trees already equal annual grains in their ratio of fruit to vegetation. But an herbaceous perennial grain, with aboveground growth dying back each year, might require a path different from those of apples or annual wheat, or even those of perennial pasture and hay crops, which have long been domesticated but are bred almost entirely for leaves and stems to feed ruminants, not for seed to feed people.

Miller and Van Tassel propose to grow closely related annual and perennial species at the same time, subject them to the same selection pressures, such as for seed size, and watch and compare how they change genetically and in form. "What I'd hope to see is an increase in seed size in both of them," Van Tassel said. This might mean that a different domestication path is not necessary. Instead, it would show that just as wild annuals became productive domesticates, so can perennials, even if, because of a perennial's more conservative life cycle, it doesn't happen quite as fast.

Such experimentation could also reveal the differences between perennials and annuals in problems like genetic load, the accumulation of inferior genetic variants, and point to solutions. It could show that success like DeHaan's in increasing seed production from intermediate wheatgrass was not a fluke. It could provide a general approach to successful domestication of perennials, and build support for building the inventory.

This experimental evolution could simultaneously pursue two or more traits, and see how they relate. For example, while one population of a species was selected, generation after generation, for larger seed size, another population could be selected to maximize the amount of carbohydrate stored in roots for winter, and a third for both characters. Does gain in one trait take from the other? How can this be worked through to reach a profitable balance? Land Institute sorghum breeder Stan Cox once said, "The history of plant breeding is the history of overcoming such negative relationships between traits."

These tests might help answer the general question of whether it is better to select for all or many desired traits at once – plants flowering in sync, large seed, plants not dropping the seed – or select for single traits in different populations and then merge them. This is a question modern breeders of annual grains have never needed to ask, because they aren't starting from scratch.

A related illustration of the variety of potential in plant genomes comes from University of British Columbia scientist Loren Rieseberg. He found that two species of sunflower, *Helianthus petiolaris* and *H. annuus*, gave rise to three hybrids, each favoring an extreme place unfrequented by the parents: *H. anomalus* in sand dunes, *H. deserticola* on desert floors, and *H. paradoxus* in salt marshes. "There isn't just one outcome [from a crossbreeding]," Van Tassel said, "it depends on how you do the selection." Human parents might relate.

The Land Institute lacks such extreme environmental diversity, but it has acreage for testing in hot summers and cold winters, one greenhouse and another in the works, and collaborators around the world, including in the tropics, who can help to grow plants. The Missouri Botanical Garden lacks agricultural facilities, but has a trove of information, including more global connections, to start and feed the research. Even together, the organizations won't provide a combination of perennial grains to solve by 2018 the problems of farming marginal land in a place like sub-Saharan Africa, Miller said. "This is a massive undertaking," she said. "We need to balance what we could do with no limits, and what we can do in three years." But in bringing together two groups of people with complementary skills and resources, she finds a powerful and optimistic worldview for work that is good for both agriculture and the earth.

Perennial grains in Africa

World researchers meet again, at the place arguably most in need of new crops

Late this summer, interest in perennial grains drew to Bamako, Mali, almost four dozen researchers, social scientists, and agriculture administrators from Africa and the rest of the world, including three scientists from The Land Institute. Research Director Tim Crews said the meeting's blend of field trips and research talks impressed upon him how hard African farmers have it to eke food out of poor soil, and how perennial grains could help. Many African soils are ancient, without the glacial mineral rejuvenations enjoyed by North America and Eurasia. Tillage makes them worse. Soil organic matter, the most important thing for farming without fertil-

Showing in Mali, northwest Africa: the diversity of people interested in perennial grains.

izer, as Africa's subsistence farmers must, runs as low as 0.25 percent, a small fraction of that in Midwestern soils, even degraded ones. Some African soils are so poor that plants in them don't respond to fertilizer. In the past farmers have raised soil organic matter by leaving fields fallow. Now the pressure to grow grain is too great, Crews said.

With their greater roots and lack of tillage, which would send carbon into the atmosphere as carbon dioxide, perennials could build soil organic matter even while feeding people. Nature's soil-building ecosystems tend toward perennials in species mixtures, and this is The Land Institute's model for a new agriculture. A colleague, Sieglinde Snapp, from Michigan State University, is working in Africa with the perennial legume called pigeon pea. The Land Institute is seeing its perennial sorghum tested in Mali and Uganda.

Land Institute post-doctoral researcher and Uganda native Pheonah Nabukalu, who also visited the plots early this year, said two sites in Uganda had been reseeded after misunderstanding led to the first planting being plowed under after its initial season. The new, larger planting showed the same problem that the first suffered: disease that ruined seed heads. But plants re-emerged from rhizomes and crowns after harvest, and produced new stands. The sorghum plants in Mali did not suffer the same disease, but faced an eight-month drought, in poor soil. About 20 percent showed perennial regrowth, and had produced seed heads by the time of Nabukalu's visit. Disease resistance might come by breeding the plants from Kansas with local resistant varieties. The African plants have only half the chromosomes of our two-species hybrid. A researcher in Africa is working on how to double the local varieties' chromosomes.

Sponsors of the meeting in Mali were the United Nations Food and Agriculture Organization, and the International Crops Research Institute of the Semi-Arid Tropics. The FAO held the first such meeting two years ago in Rome. The plan is to meet again two years hence in China. The Land Institute hosted a similar meeting last fall in Colorado.

Jamie Bugel leads a crew that cut and bagged for analysis mature heads of perennial wheat. The seeds were dry, but unlike annual wheat and most earlier perennials, in August these plants remained alive. Scott Bontz photo.

Wheat that can take the heat

For the first time, whole plots of The Land Institute's perennial wheat survived after harvest, through summer and into fall. The plants grew in ways that would leave them vulnerable in winter, but they grew. "Big progress" is how wheat researcher Shuwen Wang described this to Land Institute staff.

The survivors were offspring of perennial intermediate wheatgrass and annual durum – pasta wheat. Until now most of the annual parents that Wang used for his plants were bread wheat. Wheatgrass and bread wheat both have three subgenomes. Each of these chromosome sets came from different ancestor species that hybridized in the wild. Durum has only two of the sets. This makes it less influential when bred with wheatgrass. The multiple genes for perenniality in wheatgrass can come more to the fore in the durum hybrid.

In Kansas, annual wheat usually has died and been cut by late June. Intermediate wheatgrass seeds finish ripening a little later. After that the plant takes it easy through the hottest part of the year. When it sends up new greenery, the aboveground growth is only vegetative, just stems and leaves, to capture sunlight and carbon and invest for winter, at the surface in crowns, and belowground in roots and rhizomes. Only come spring does the plant form reproductive growth points that will shoot up to flower and set seed.

Wang's earlier perennial wheat pushed up second-round reproductive tillers the same year that the regular, desired tillers were made, sometimes beginning even before harvest. These plants died, not because they aren't perennials, but because they didn't keep the perennial parent's conservative pacing for sex and seed once a year.

The reproductive tillers of the durum crosses do not emerge so fast. When Land Institute workers in August cut the plants with sickles, few new seed heads were showing.

But Wang pointed to the base of the plants: hidden among them reproductive growth tips were already forming. By fall the plants were attempting new seed heads. They beat the heat but would be vulnerable to cold. "I expect a proportion of the plants, not all, will be killed," Wang said. Survival depends on how many late tillers appear, the depth and length of freezes, and whether the plants have those enduring underground stems called rhizomes.

In coming years Wang will harvest seed from the durum hybrids and grow increasingly large populations. He will search them for plants that control reproductive growth. A wheat like this already exists, from a researcher in Montana, but it does not produce seed well. How this variety called MT-2 manages itself like a proper perennial is not clear, but is under study. The answer might include the genes that control flowering time.

Meanwhile Wang will expand genetic diversity of his plants by crossing wheatgrass with more durum varieties. He will also breed using wheat plants that have had parts of their flowering time genes silenced chemically, at the University of California, Davis.

What will people do for dirt?

An awful lot, yet they still lose it – but that could change with perennials

SCOTT BONTZ

The Spaniards who conquered much of the New World in the 14th century were keen observers of agriculture, and many of them were good writers. Their annals described farms in Mexico as prosperous and pleasing. What the conquistadors did not perceive, Angus Wright said at The Land Institute's Prairie Festival in late September, was how this prosperity had been a lucky, hard-won moment. For hundreds of years, shifts in the winds had tumbled the Aztecs' exquisite agricultural technique. So would Spanish additions such as draft animals.

Underlying the complex interactions of resources and people that make for civilization is soil. Soil's degradation and loss is not all that brought down ancient Greece, the Mayans, and various Chinese powers. But Wright, a historian of Latin America and a pioneer of environmental studies, said, "Even before we were following agriculture, we were following dirt." Rich soil makes rich plant and animal life. What agriculture did for soil was to heighten our awareness. It got us to see soil directly – running through our hands, running toward the sea – and to realize it was finite.

So any civilization will have a rich repertoire of responses to soil loss. Those that collapse aren't made up of idiots or quitters, Wright said. For thousands of years, civilizations have devoted intelligent people, and great energy and technology, to fight soil degradation. But annual tillage is about tearing things up. The infrastructure to check these losses is not resilient.

The people of the pre-Columbian Western Hemisphere developed about one-third of humanity's crops, including the biggest, maize. These people lacked the wheel, but Wright said they did not lack agronomists, the scientists of farming. They classified soil by dozens of types, and adapted to each type their agriculture. They fertilized with manure, and with minerals that they mined. Their irrigation designs included capture of more minerals, and of silt, for soil enrichment. They planted trees that fixed nitrogen. To the field they hauled for soil nourishment forest debris and algae. They annually raided the nests of leaf-cutter ants, farmers themselves, for eggs to use as fertilizer. "They scoured the environment for nutrients," Wright said. Agricultural technique wove these people's societies. Without ox or horse, they daily provisioned the metropolis that today is Mexico City by canoe and canal. Labor was immense and highly coordinated. Society was stratified and martial.

The ability to store and move food came with farming, and so did class division, not just in Mexico, but also throughout the world. Also universal is how the desire for wealth from land brings war. Wright said that with farming we made fabulous rationalizations for what is really about getting more wealth from soil.

The Spaniard Coronado is believed to have journeyed from Mexico to within another day's ride of what became The Land Institute. He sought cities of gold, not soil. But another Prairie Festival speaker, Ricardo Salvador, of the Union of Concerned Scientists, said the treasure hunter came from a ranching family. And when Coronado

Claire Trail weighs alfalfa cut from a test plot and piled in a tarp. The Land Institute studies how growing this legume with intermediate wheatgrass might improve soil fertility and grain yields with less synthetic fertilizer. Replacing annual grains, the two perennials would also conserve soil and improve its structure. Scott Bontz photo.

saw massive herds of cattle – bison – he recognized the North American prairie's tremendous wealth. "It must have been overwhelming," Salvador said.

Back in Europe, farming in medieval times had expanded eastward, leveling forests and driving out the lion. Soil there remained fertile for centuries because of recent enrichment by rock-grinding glaciers, and because of elaborate farm methods. But by the 17th and 18th centuries population had grown, and with it concern about soil fertility. Technique was no longer enough; the savior of Europeans would be new land in what they considered the New World. The first big imports were sugar and cotton, but there followed crucial grains like wheat. The Western adventure's goals shifted from God, glory, and gold, to basic commodity production. Europeans and their colonial offspring took all they could of the Americas' soil fertility and wealth. Then they resorted to fertilizer from mountains of South American bird guano, then South American nitrate mines, and then the Haber-Bosch process of synthesizing ammonia from air. Finally, after world wars over territory, the Europeans restored soil fertility with this fossil-fueled chemistry. But without the soils of the New World, Haber-Bosch would not have been so meaningful, Wright said. What saved Europe was conquest – conquest that enslaved Africans and killed natives.

"What will people do for dirt?" he said. "Well, just about anything."

In 1769 Benjamin Franklin wrote that wealth comes to a nation by three means: war, which is robbery; commerce, which is generally cheating – he meant not business per se, but when a retailer hides his costs, leaving the buyer with no notion of a fair price; and agriculture, "the only honest way." Franklin said the farmer virtuously benefitted from God's grace with "a kind of continual miracle" in the growth of food from seeds. Salvador said this was only true before fossil fuels, and now agriculture is war.

Agriculture after World War 2 vastly expanded chemical technique, exploding grain yields, but also pollution by nitrates and pesticides. And it still loses soil through the harassment of annual cropping. So Wright asked, "Why not think about the idea that we've been going about this the wrong way for several thousand years?" He had begun his talk saying that historians aren't really detached and objective. Their work is a long-winded way of telling us what to do. "Really, we're scolds," he said. Now he made a suggestion.

Wright and Wes Jackson worked early on in the new environmental studies program at California State University in Sacramento. Jackson left, and in 1976 he and his wife at the time, Dana Jackson, began The Land Institute. He thought humans could build soil fertility even while making food, by mimicking what had long already done so: natural ecosystems. This would mean not just drawing a plant from the wild and making it a domesticate, but recognizing how the plant worked as part of a whole system of species and naturally occurring minerals and water. Agronomy would use that system as a model. Wright, chairman of The Land Institute's Board of Directors, said that given the alternative's history of pain, suffering, and destruction, "Ain't it worth a try?" He said, "Maybe we would avoid all of those losses. And now I think we're probably going to do it. I think it's going to happen."

Why not invest in it, he asked the Prairie Festival audience. Considering the possible consequences, he said, invest millions. "What will people do for dirt? I will say let's do this, and see if it works."

Land Institute shorts

To read wheatgrass DNA

In a job that researcher Lee DeHaan compared to assembling a jigsaw puzzle of 2 million pieces, the US Department of Energy's Joint Genome Institute will help sequence much of the genetic code of intermediate wheatgrass, a perennial that The Land Institute is developing as a grain crop, and which has the food name Kernza®. US Agriculture Department and Kansas State University researchers made the proposal with DeHaan. Sequencing means reading the chemical alphabet of an organism's DNA. Learning the sequence won't immediately explain gene functions, but will be a crucial step toward such understanding, which could help toward success with wheatgrass as a grain. The project is expected to take several years. The Joint Genome Institute supports the Energy Department's work toward clean energy and environmental improvement. It has enough sequencing capacity for other, broader work, and comparing the complex wheatgrass genome to the well-known genome of wheat might bring helpful general knowledge about the differences between perennials and annuals.

Growing roots in Denmark

Danish scientists will include two species of plants from The Land Institute in a battery of 24 towers, 13 feet tall and with windows for learning how different roots might improve soil health and sustain agricultural. The institute's plants involved in the study are intermediate wheatgrass and silphium. The research is at the University of Copenhagen, under crop science professor Kristian Thorup-Kristensen. The towers have sides that are not only transparent, but can be opened to the soil and living root architecture for measure of things like water flow, nutrient absorption, and variation in the role of microbe life among the plants.

Swedes will test wheatgrass

The Lonnstorp Research Station in Sweden will host an ecological study of growing The Land Institute's intermediate wheatgrass, alone and with a legume. The study will measure things such as soil carbon changes, productivity, and how well the plants take up nitrogen, and compare results with those from conventional and organic annual cropping. Lonnstorp this year grew plants from seed supplied by the institute, to increase the seed available for the study that will begin next year. The project's lead scientist is Erik Steen Jensen, who attended an international perennial grains conference organized last year in Colorado by The Land Institute.

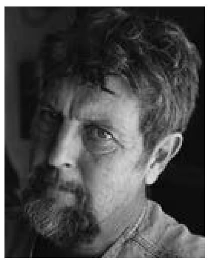
Press and presentations

Land Institute staff members spoke in New York, North Carolina, and Minnesota. Scheduled talks are January 11 in Saskatoon, Saskatchewan; and January 30 in Concord, New Hampshire. For more, see Calendar at landinstitute.org, or call 785-823-5376.

Desert prophet of new food crops

For 40 years Richard Felger has promoted native plants to feed the Southwest

GARY PAUL NABHAN



Richard Felger has always been a little ahead of his time. Even before he was a teenager in southern California, he cultivated rare cacti and orchids at home, and kept three alligators in his bathtub. Before he graduated from the University of Arizona, he shadowed some of the world's greatest desert ecologists. On his first trip down to Alamos, Sonora, he realized what would drive his career: the Sonoran Desert was full of wonders, and some of them were delectable.

Within a few years, Felger had suggested that we design farms to mimic desert ecosystems. In several papers published in the late 1970s, he and his colleagues pioneered a way to identify new crops for arid lands. He proposed for domestication those desert plants that would be most reliable for producing food, with the least irrigation and tillage.

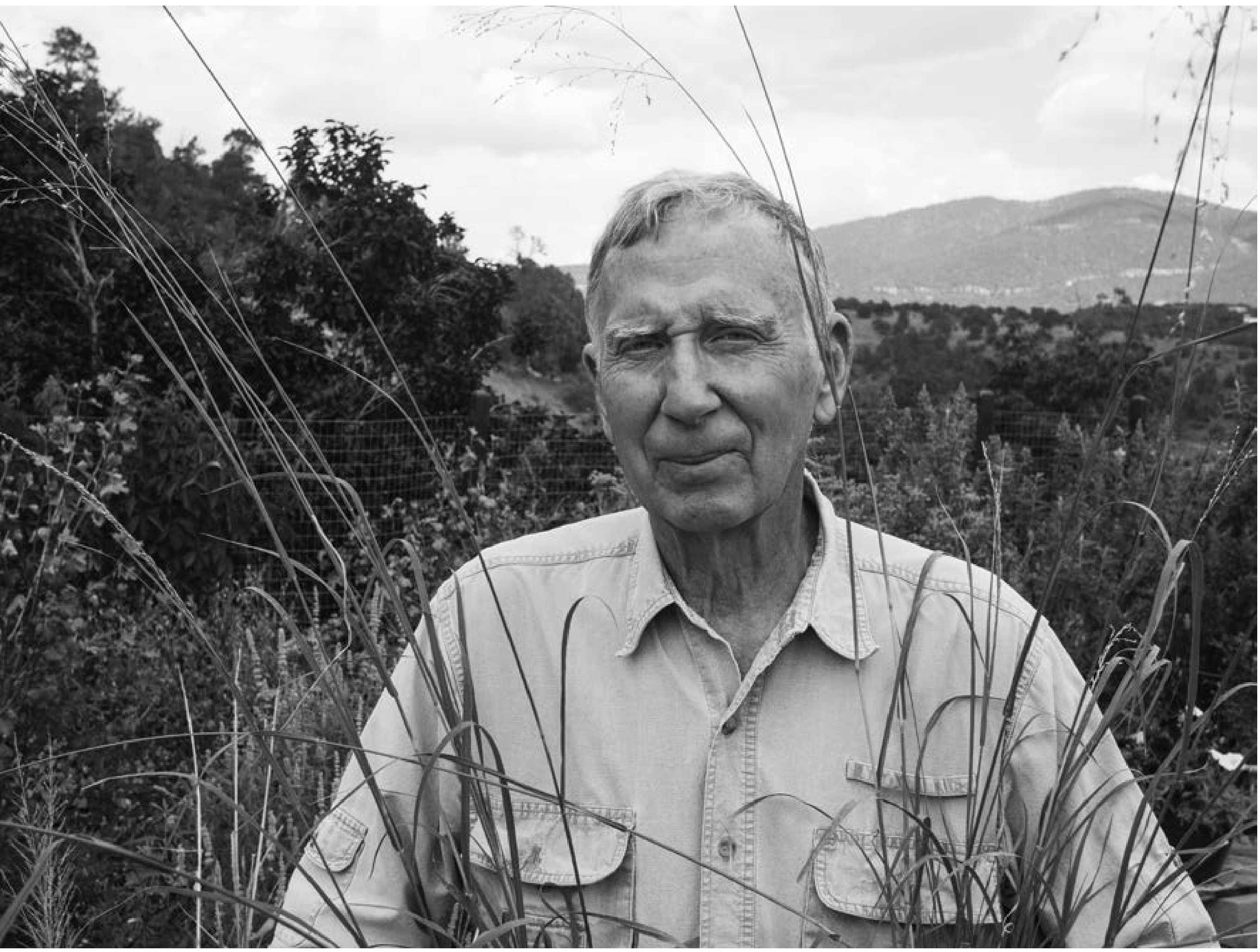
The Sonora Desert natives that Felger initially proposed be cultivated included mesquite, agaves, fruit from organ pipe and prickly pear cactus, tepary beans, chiltepin peppers, grain from a saltgrass called "nipa," amaranth, and oil from buffalogourd seeds. Felger predicted that agriculture in the Sonoran and other deserts would soon need to be restructured from the bottom up. His vision was to "fit the crop to the prevailing environmental conditions rather than trying to remake desert environments to fit temperate, water-hungry crops." He and his colleagues proposed that farmers plant native, drought-hardy crops in mixtures of species, mostly perennials. Unlike the Land Institute's efforts with new prairie crops, Felger chose not their lengthy domestication and hybridization, but instead to find wild species and a few common cultivated desert land races that seemed "ready to go" for arid farming. They could efficiently use harvested rainwater, rather than the pumped groundwater required by conventionally recommended crops – cotton, alfalfa, pecans, citrus, lettuce.

But his message was largely ignored, if not outright dismissed, by most of the crop scientists working in the same arid region.

Now many Arizonans wonder why mainstream crop scientists didn't listen to him sooner. With groundwater levels plummeting across the desert Southwest, and the Colorado River's reservoirs reaching the lowest levels since it was first dammed, both water rationing and steep price increases for irrigation are kicking in. Desert-adapted crops are needed more than ever. Felger recognized the Sonoran Desert's apparent barrenness as "deceptive," and showed how its residents could enjoy a level of local food security unknown for decades.

Although Felger began his career as a desert herpetologist, he soon gained renown as the Sonoran Desert's most knowledgeable botanist, writing regional floras and describing new species or novel uses of well-known ones. It was his earliest work describing the historical uses of plants by the Seri Indians that transformed his research into a quest for future food crops. The Seri demonstrated to Felger not only that these plants were edible, but also that they were delicious.

Though familiar with the Sonoran Desert's overall plant diversity, he chose to focus on a few of its edible species – including two that were wild-harvested by the Seri and their Mexican neighbors – for their potential to become crops in arid climates. His technical papers adorned the covers of prestigious science journals, but at times were



Early in his career Richard Felger began arguing that we design farms to mimic desert ecosystems. He has finally seen several of the native plants he championed make their way to market. Photo by Bill Steen, who with his wife, Athena, directs the Arizona-based Canelo Project, "connecting people, culture, and nature." They have written books about building with straw bales and natural materials.

more widely celebrated beyond the Sonoran Desert than within it.

Most field crop scientists in the Southwest's land grant agricultural colleges dismissed Felger's radical suggestions, and that future water scarcity might drive into obsolescence the furrow irrigation of food crops adapted to temperate climates. They could not imagine that accelerated climate change might make the desert hotter, drier, or more saline.

Audience or no audience, grants or no grants, Felger has continued desert food studies for well over half of his life. A youthful-looking 81, he exudes whimsy and humor, refusing bitterness over lack of recognition by his peers. He is hopeful, not cynical: "The usual complaint about new crops you hear when you talk with well-funded institutions or government programs is that most of native desert crops are not well-suited for industrial scale harvesting and processing. The agricultural industry still turns its nose up at the idea of new crops. It doesn't want to fund their development unless it can acquire all proprietary rights to the species, which I will not and cannot offer."

But the times – and the climate – are changing. And Felger has found new, more receptive audiences: "Last year, when I spoke at the conference of the New Mexico Organic Farming Alliance, I realized that hundreds of small-scale farmers fully get what I am trying to do. They are eager to participate because of the challenges they are currently facing, … and are helping me get these promising crops evaluated under field conditions on their own farms."

Felger now realizes that his food crop candidates are not only to solve some of the most pressing problems facing desert agriculture, but that their edible, delectable heritage food products are highly marketable: "Most of the world has recognized by now that there will soon be no cheap water for irrigating crops, nor cheap fossil fuel for tillage. Many farmers actually want to transition to no-till. And now, there's a vibrant locavore movement that is willing to pay for sustainably grown foods. These various threads are being woven together."

When I tracked Felger down in his recently adopted hometown of Silver City, New Mexico, I asked him to document which of the food crops he proposed in the 1970s had already hit "pay dirt" – that is, which crops were being grown commercially. Still active and prolific in describing desert floras, and evaluating native plants for potential domestication, he had never taken a breather from his work long enough to calculate his batting average. Together we looked back and found that five out of six of his first candidates have already been enthusiastically adopted by farmers and chefs.

It may be hard for contemporary Southwest foodies to recall, but in the mid-1970s, foods like mesquite flour, prickly pear fruits and syrups, dried tepary beans, chia seeds, popped amaranth grains, and agave nectar were virtually unknown in the American marketplace. Amaranth seeds and greens, prickly pear pads (nopalitos) and fresh fruits (tunas) were widely available in Mexico, but they were often looked down upon as "poor people's" survival foods.

While not directly involved in their commercialization, Felger was among the vanguard of those who elevated the status of such foods. Through dozens of lectures and popular magazine articles, he brought Mexican scientists, chefs, and innovators to take more pride in the cultural heritage, nutritional quality, and flavors of their ancient foodstuffs. Interest in the United States eventually grew as well, with the likes of the National Research Council, the Rodale Research Institute, and Friends of ProNatura taking heed.

Today, amaranth grain, tepary beans, and chia seeds are ubiquitous in health food stores, as are agave nectar and prickly pear syrup. Mesquite is not only being grown as a tree crop for food and wood by the Arizona Mesquite Company, but nearly a dozen hammer mills and several festivals help Arizonans to process their own wild-harvested mesquite pods.

Additionally, the Seri Indians, from whom Felger first learned about mesquite's food value, have had their traditional fire-roasted mesquite flour boarded onto the Slow Food International Ark of Taste, the only global list of imperiled or neglected foods. It is now featured at the Mitsitam Cafe at the National Museum of the American Indian on the Washington Mall, and in bars and coffee shops in Tucson.

When Felger first wrote on Sonora's several agave species, including water efficiency double that of maize, making mescal from them was strictly bootleg. But within a decade of his first publications in Sonora, scientists and farmers there were emboldened to bring at least two native species of Sonoran Desert agaves into cultivation in sizeable plantations. At least four brands of Sonora's mescal bacanora are now sold in Arizona, and most of them now use cultivated rather than wild plants.

When Felger and his colleagues began to evaluate the chiltepin as a potential food crop, the entire harvest coming into Arizona from Sonora was wild-harvested. Soon, Sonoran innovators such as Alfredo Noriega and Manuel Alberto Lopez had carefully selected from diverse wild foundation seeds those that would do best under cultivation. Now cultivated chiltepin sales sometimes exceed that of wild-harvested chiltepins.

If there is any take-home message from Felger's work over the past four decades, it is that innovations in our food systems most often emerge from creative people on the margins, not from the biggest, wealthiest research institutions or agribusinesses. This clearly rings true for The Land Institute. It was Felger's deep familiarity with desert plants and ecosystems that enabled him to envision an alternate future for food crops in the arid Southwest.

Felger is now partnering with Silver City neighbor Gregg Dugan, a tree crop specialist who helps advance no-till production of perennial food crops in permaculture systems. They work with several farmers on Arizona Indian reservations, in Sonoran villages, and in New Mexico farm towns to get crops like mesquite and Apache redgrass cultivated on a larger scale. Their work was recently supported by a specialty crop grant from New Mexico's state government – the kind of award that was never granted to Felger during his 40 years of promoting the same crops in Arizona.

But the question in Felger's story is not how visionaries like him secure funding and recognition for their innovations that may benefit society. Rather, it is this: Are we desert dwellers ready to eat a diet that features crops suited to our arid environment, or will we continue to see the desert depleted by the furrow irrigation of water-guzzling and largely unsustainable food and fiber crops? This choice is ours to make.

Gary Paul Nabhan has written several books about agriculture and food, including "Growing Food in a Hotter, Drier Land: Lessons from Desert Farmers on Adapting to Climate Uncertainty" and "Food, Genes, and Culture: Eating Right for Your Origins." Forty years ago he began his work on desert foods as Richard Felger's intern and research assistant. The photo of Nabhan is by Dennis Moroney.

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From left, Sheila Cox, Claire Trail, and Pheonah Nabukalu harvest seed heads of perennial sorghum. For Nabukalu's observation of Land Institute sorghum in Africa, see page 16. Scott Bontz photo.