The Land Report

A publication of The Land Institute / Number 86 / Fall 2006

The Sunflower

Why It's a Crop, What This Costs the Land, and How We Work to Change That

Contents

Features

Regulars

Cover: Kansas Sunflowers, *by Birger Sandzen. Linoleum cut, 8⅞ by 12 inches, 1933. From Birger Sandzen Memorial Gallery. The story about how annual sunflower became a crop, and what we're doing to make it a perennial, begins on page 4.*

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.

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ISSN 1093-1171

The Land Report is published three times a year.
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At the Land

Perennial Grain Breeding

In the seed harvested from plants that survived last winter, we saw progress with perennial sorghum. Of 264 plants, 56 (21 percent) had seed that looked better than any from perennials of past generations. Of those 56, 38 also had seed heads progressing toward the compact form of conventional grain sorghum's. Most of the other 226 plants had wild, open heads.

The following weights, in grams per thousand seed, show that we are improving the average grain size.

■ Average of three perennials of the previous generation: 5.7 grams.

■ Average of the 56 new-generation perennials that had improved seed: 10 grams.

■ A commercial sorghum hybrid: 25 grams.

Eleven of the new perennials had thousand-seed weights of 12 to 13 grams, about half that of grain sorghum's.

The new perennials are shorter than previous ones, but not short enough to be a mechanically harvested grain crop. The overall appearance of the best perennial plants is probably comparable to that of forage sorghums, which are typically taller and lower in grain production than grain sorghum.

We began our second round of selection to domesticate the perennial intermediate wheatgrass. The 50 plants selected in Round 1 were mated with each other to produce seed for Round 2. In October, we put 4,000 resulting plants in the field. After they grow for two years we will harvest and measure their seed to select the plants that will make up Round 3.

After years of work to make fertile hybrids of wheat and perennial relatives, we had enough seed to put 2,000 plants in the field a year ago. Those most like wheat all died this summer. However, plants that were closer to wheatgrass—smaller seeds and more slender stems—are thriving. These plants all came from crosses with wheat that has 28 chromosomes—rather than the 42 in bread wheat—or were the result of backcrossing to wheatgrass. So, we now know where to concentrate our efforts in making crosses this winter.

Publications

In the August *BioScience*, Land Institute scientists laid out our work of breeding perennial grain crops: why and how we're doing it, and its challenges and prospects. *BioScience,* the magazine of the American Institute for Biological Sciences, gave the report more than nine pages, and an editorial in support.

In the conclusion our scientists say that "the road leading to perennial grains will be long, and it may often be rough; however, the time required should be put in context. Had large programs to breed perennial grains been initiated alongside the Green Revolution programs of a half-century ago, farmers might well have had seed of perennial varieties in their hands today."

Kendra McLauchlan's report on her Land Institute graduate fellow research was in Volume 16 Number 1 of the science journal *Ecological Applications*. McLauchlan, with co-authors Sarah Hobbie and Wilfred Post, measured how fast levels of organic matter increase in soil when fields of annual crops are converted to perennials plants.

Soil richer in organic matter is more fertile, and absorbs and drains water better for plants. Soon after land is converted to annual cropping, soil organic matter levels fall by about half. That it climbs again with restoration to prairie was known, but how fast was not.

The scientists studied Midwestern fields whose return to perennial grassland spanned 40 years. They found that after cultivation ended, organic matter grew in the top 4 inches of soil at a constant rate, one that would equal in 55-75 years the organic matter of unplowed native prairie.

By perennializing the major grain crops, The Land Institute aims to restore soil to preagricultural conditions while still producing food.

Presentations

Land Institute President Wes Jackson spoke at the Ecological Society of America's annual meeting, in Memphis, Tennessee, on August 10, and two days later at the Ohio Prairie Conference in Dayton, Ohio. He talked about reforming agriculture to work more like natural ecosystems if it's to be ecologically healthy.

In Salina on September 10, Jackson led a discussion of *An Inconvenient Truth*, the documentary film about Al Gore's campaign to show how humans are causing rapid global climate change. Jackson thought Gore did well explaining the problem, but was wrong that we can cut greenhouse gas emissions to solve the problem while keeping economic growth. For a sustainable economy he suggested instead the standard of resilience.

Before the Kansas Department of Health and Environment on October 26, Jackson argued against construction of new coal-fired power plants in western Kansas.

New Board Member

Lloyd G. Schermer of Aspen, Colorado, joined our Board of Directors. He is past chairman of Lee Enterprises, and worked at its newspapers in Davenport, Iowa; Kewanee, Illinois; and Missoula, Montana. Long engaged with conservation, he is an honorary life member of the Smithsonian National Board and member of the boards of Aspen Institute and Aspen Center for Environmental Studies.

The Sunflower: Why It's a Crop, What This Costs the Land, and

Stories by David Van Tassel, photos by Scott Bontz

In whimsical moments I think of sunflowers as the nobles of the crop world. Young plants assembled in fields perform a stately dance. Their flower buds rotate to face east for dawn's light, then, with quiet dignity, leaves and buds swivel in unison with the sun until dusk. Crowned with gold, the man-sized heads of mature plants withdraw from the dance to soberly remain facing east and devote themselves to childrearing. In their twilight weeks, the grizzled heads bend low, under the weight of up to 2,000 fat seeds, in exhausted dignity.

This kingly crop's distant sires were an unruly, profligate rabble that is with us still. The common annual sunflower is an adaptable and sometimes aggressive rascal. Found in squalid ditches, overgrazed patches, wallows and other "waste places" throughout North America, they make do with what resources they can find, often growing only a couple feet tall. Stumbling upon abundant nutrients and moisture, these prodigals can explode to 12 feet tall, branch wildly and spawn hundreds of small heads, which together drop tens of thousands of seeds.

The massive seed production drew Native American gatherers to patches of sunflower growing in the wake of floods, landslides, camps and bison stampedes. We'll never know exactly how they transformed this weed into a crop 4,000 years ago. We are not even sure if the change happened in the current Mexico or eastern United States—or

At far left is a wild annual sunflower. Next to it is a crop sunflower, also an annual, bred to make lots of big seeds. The three plants at ri

How We Work to Change That

both places simultaneously. What we do know is that natives ground the seeds into flour for thickening soup or pounded them with berries, meat and tallow into pemmican. They also extracted purple pigments from the seeds' black hulls to dye baskets and other things, and roasted and brewed hulls for a drink like coffee.

Domestication could have happened almost automatically. Noting that sunflowers appear where disturbances killed prairie or forest perennials, the first sunflower breeders might have deliberately scattered leftover seed in these spots—or even intentionally scuffed up the ground, not leaving the process of disturbance to chance alone. And as they favored particular plants, the selection pressures shaping the wild sunflower changed. Genes that made a seed or seed head larger and more likely to be noticed and harvested by people outcompeted genes that made seeds better at "shattering"—falling to the ground or blowing in the wind.

With 10,000 years of results from the Great Agriculture Experiment, a latter-day plant breeder like me can argue that a serious downside to "automatic" domestication was that it favored annual plants, which allow erosion that brings down civilizations. Though there are 38 species of perennial sunflowers in North America, many with attractive features such as profuse seed production or the ability to grow in rocky or dry places, the only one to have been domesticated was an annual.

ight are wild perennials. Between are the results of cross-breeding on the way to a perennial crop sunflower.

There is evidence that people worldwide once harvested any wild edible seeds, perennial or annual. It was probably mostly perennials, since they are the vast majority of plants in forest and prairie. How did the perennials elude domestication as grains? Genetic makeup begins to shift as soon as people plant the same seeds that they harvest. But with perennials there was no need to plant seeds. A family simply returned to the grass swards, sunflower patches or plum thickets each year to harvest. It's the annual plants that had to be planted if the family was not content to simply wait for the next flood or other disturbance to open up a site for annual sunflower.

The choice of annuals—for sunflower and all the other grain crops, from which humans get most of their calories—is especially regrettable given the scale of agriculture today. Annuals cover and protect soil for only a few months. Most Native American farmers do not seem to have caused serious soil erosion, probably because their farms were small, and the perennial vegetation around them vast and healthy. Where large populations developed thanks to intensive, often irrigated, agriculture, soil erosion did occur, and eventually proved just as devastating then as now. In his excellent and thorough book *Collapse*, Jared Diamond describes societies destroyed at least in part by erosion, including the Native American Anasazi and the Maya.

Soil forms as rock crumbles—a very slow process. Where soil accumulates it makes lush plant growth possible by soaking up water from sporadic storms for later plant use. Soil is also a reservoir of essential minerals that are present in bare rock, but which dissolve out of it in meaningful amounts only when the rock is finely powdered, warm and wet. Without the protection of plants—their leaves softening the impact of raindrops and their roots forming a dense protective matrix—water and gravity quickly strip sloping land of its covering of soil and soluble minerals.

Still, the domestic sunflower, corn plant and other crops are among humankind's greatest achievements. That later generations and different societies have grown them too greedily and suffered the consequences is no fault of the original breeders. Their work, though in some senses "automatic," took generations of careful labor, and keen botanical instincts and knowledge. My Land Institute colleagues and I stand in awe. But we want to try the experiment again, this time with perennial crop plants.

Not only do perennial plants protect the vital soil resource:

■ They invest in deep, massive root systems, which pays off in dry years when they can reach far down for moisture and nutrients.

■ They reuse their root systems, so do not spend as much on rebuilding as annuals, which must start their roots from scratch each year. Annuals are often much more shallow and always less massive than the root systems of perennials.

■ They emerge and green-up much earlier than annuals. Annual crops have a double handicap: First they must start each spring from a tiny shriveled seed—compared with the fat, succulent underground stems of most perennials. Second, farmers cannot plant them until the soil is both dry enough to till and warm enough for seeds to germinate immediately—before they rot or get eaten. Spring storms often delay planting and give farmers a great deal of anxiety. In central Kansas, we often see farmers planting annual sorghum in the spring six weeks after our perennial sorghum emerged and began to grow rapidly. Conversely, in the fall many of our perennial crops stay green even after harvest, photosynthesizing and potentially replenishing spent energy reserves. Even in climates where perennials go dormant in the winter, they still are capturing sunlight many more days in each year than their annual counterparts.

In my work with wild perennial sunflowers, every so often I notice a plant with extra-large heads. Closer examination shows that these oddities are actually two or three normal heads that grew unusually close together and fused. The sunflower family's defining feature is individual flowers clustered to form a "head." These individual flowers are called florets. Those around the edge each produce a single long petal in addition to the normal small petals. This makes the head appear to be a single flower. Given this family's ability to "telescope" flowers spread out along the stems and branches into compact heads, perhaps it is not surprising that whole heads can fuse. I have not seen this in wild annuals, but I have not spent hundreds of hours with thousands of them, as I have with perennial species. It is not hard to imagine that fused heads were noticed from time to time by native farmers. If you are harvesting heads by hand and tossing them into a basket or backpack, it is faster and easier to pick one big head than three little ones.

In addition to favoring annuals, "automatic" domestication lets some undesirable traits creep in. Many traditional sunflower varieties are so tall—a result of competition for light—that they make harvest difficult, by hand or machine. Tall plants with heavy heads also topple in rough weather.

While a tall sunflower can outproduce shorter neighbors, a whole field of tall plants invests uselessly in large stalks. The modern farmer wants disciplined plants that, for the productivity of the whole group, don't compete among themselves. Sunflowers must be planted carefully to avoid crowding, which results in lots of leaves and stems at expense of water and nutrients for seed production.

Plant breeders help, with varieties that are short, investing less in stalks; uniform in growth rate and flowering, so some don't trigger in others compensatory growth to avoid being shaded out; and "determinate." Determinate plants grow to a fairly predictable size, flower, set seed and go dormant—or die, in the case of annuals—together.

Modern crop sunflowers are so determinate that if you cut off the main head, many cannot branch out to produce secondary heads. This is not a theoretical scenario. One weevil species specializes in sunflower decapitation, often meaning zero seeds produced by targeted plants. The inability to recover by branching hurts the evolutionary fitness of an individual plant. Branching is also a kind of a weapon that sunflowers use for suppressing neighbors. Plants that can't recover from the loss of one head and can't branch out or get tall if challenged by a competitor won't pass on their genes.

And there are other drawbacks. The large heads and nonshattering seeds seem to invite birds to perch and feast. In the modern sunflower field, however, it is the breeders who make all the decisions about which genes get passed on, and their choice to quell competition increases yield of the whole group.

While I have seen birds alight on wild perennial sunflowers, they are typically finches or other small seed eaters. Larger birds would bend over and perhaps break off the small wild heads on their slender stalks. And pecking at the heads shakes most of the seeds to the ground where it is harder to find, especially if the soil is wet. But in commercial sunflower fields near attractive habitat or migratory flyways, losses can be as high as 40 percent. Losses of 4 percent are common on the Great Plains. Surveys estimate that blackbirds alone eat 2 percent of the U.S. crop, a loss worth $7 million to $10 million.

Whether our perennial varieties will end up with more than one head per stalk remains to be seen. I can imagine that a plant with several dozen heads might be less vulnerable to blackbird damage than today's single-headed annuals, though more vulnerable than shattering wild sunflowers. Mechanical harvesters don't care whether they are harvesting a single huge head or many smaller ones. We have harvested a number of small-seeded, small-headed species successfully using standard combine-harvesters.

Regardless, I still am breeding for heads somewhat larger than the average wild plant's. One reason is that it will be easier breeding synchronously ripening heads if there are fewer of them. Synchrony is important because it allows us to harvest the whole field as soon as the heads are ripe and before the birds get all the seeds. Another reason is that large heads might inevitably result from selecting for stiffer stalks that resist flopping over. The size of the meristem, the plant's growing point, influences both stem diameter and organs like leaves and flowers. Finally, it may be impossible to increase the size of the seeds very much without increasing the size of the heads. Annual sunflower heads expand dramatically as seeds fill. We want larger seeds because they sprout faster and get ahead of weeds, because they are easier to separate mechanically from dust, chaff and weed seeds, and because they have proportionally more oil "guts" and less indigestible "skin," or seed coat. For the same reason, most of us would rather peel big apples for a pie than a bunch of little ones.

To Shatter, or Not to Shatter

Plants have invented diverse and often extreme methods for spreading their seeds around. Seeds may be winged for flight, as with maples, or buoyant for long ocean voyages, as with coconuts. This level of creativity and investment tells us that there is serious competition for what ecologists call "seed dispersal." Plant breeders call it "shattering," because almost all dispersal mechanisms require that seeds, fruits or whole branches break off of the mother plant.

One of the first steps a plant can take toward domestication is to become "nonshattering"—to hold its seeds indefinitely. Then its only hope for the survival of the next generation is in the hands of humans. This was a good bet for the crop plants. By teaming up with humans, their offspring occupy the vast majority of the fertile spots on the planet.

I can think of one group of wild plants with delayed shattering: trees and shrubs with nutritious fruit. In the same way that grains have come to rely on humans for dispersal—and reward them with large, nutritious grains—wild berries and fruits rely on birds. They attract the birds with the promise of sweet fruit and count on most of the seeds passing the gut unharmed to be deposited far away.

It is no accident that most of our perennial food crops are berries and fruits: They had already been "predomesticated" by birds—made slower to shatter and relatively digestible. Our ancestors had only to choose the trees with the sweetest, largest and least seedy fruit.

While I'm unwilling to predict perennial crop sunflowers' head size, I'm surer about the stalks. Perennial plants that die back to the ground each winter—"herbaceous perennials"—have their main stems safely underground. Each spring, side buds on those main stems break dormancy and become branches—the vertical stalks that we see. The bud at the tip of each main stem continues to grow horizontally away from the center of the clump, preparing the way for the clump of stalks to grow in diameter. To better understand this, think of the underground stem as the trunk of a tree and the stalks as branches—all rotated 90 degrees. Just as trees each year both get taller, by growth of the main stem, and produce more side branches, herbaceous perennials spread horizontally and send up increasing numbers of stalks. So I am almost certain that perennial sunflowers will look quite different than annual sunflowers. Instead of a single stalk bearing a single massive head, I expect to see a cluster of stalks each with one or more heads.

One implication of this is that none of the current knowledge about how to space sunflower plants for optimum yield will be of any use. Will one perennial clump substitute exactly for one giant annual plant? Probably not. Will it be better to have dense clumps of stalks separated from each other, or low-density clumps that blend indistinguishably from neighboring clumps?

Given the challenges described, you might wonder why there is continued interest in annual crop sunflower, and why we should devote resources to its reinvention as a perennial. Some attractive features of annual sunflower are its short growing season—probably one explanation for its success in northern climes—and its drought tolerance. Though its broad leaves waste water, its deeper roots can get more of it from drier soil.

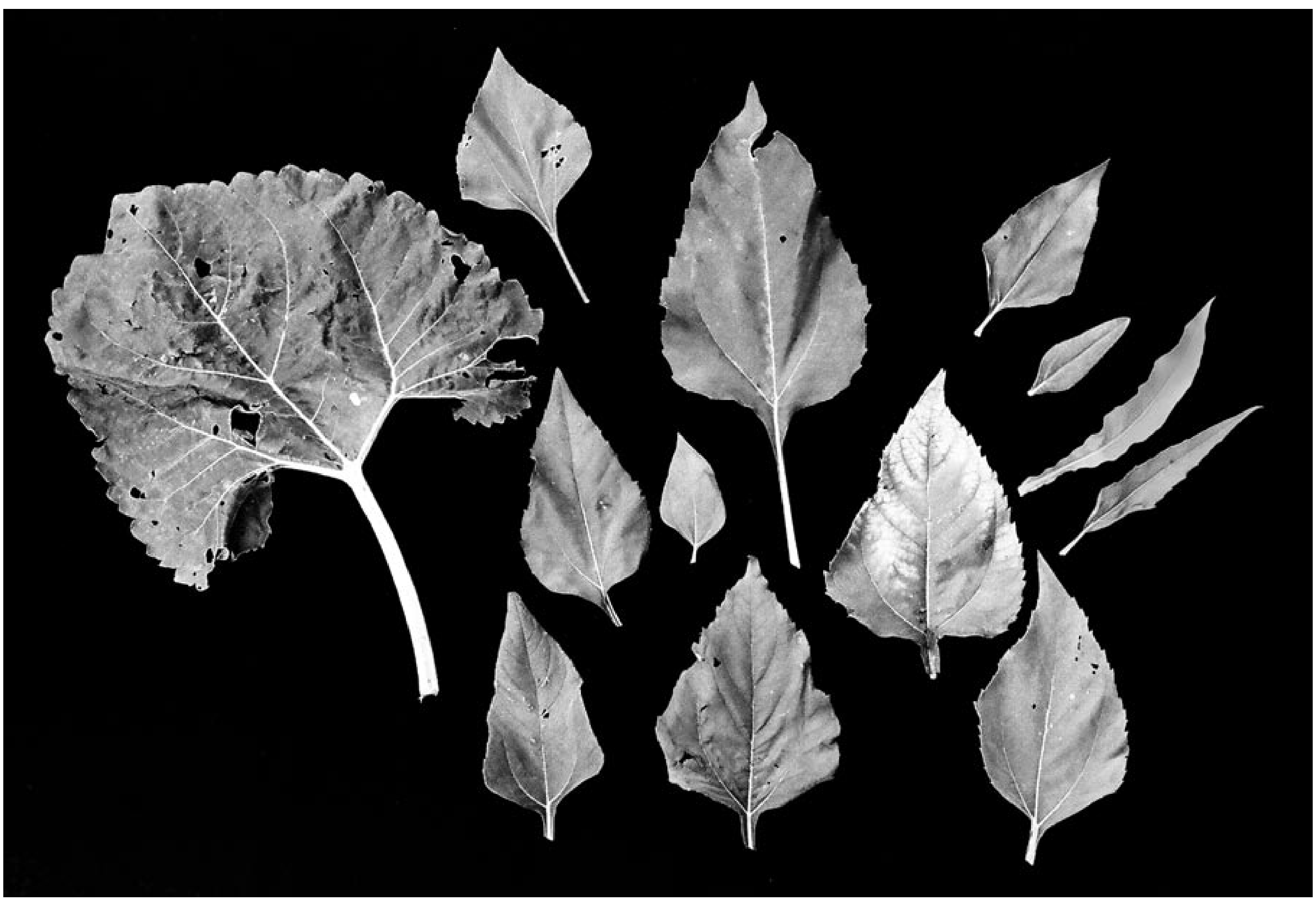
We suspect that perennial sunflowers are also deep-rooted and able to draw moisture from soil too dry for most crops. With narrower leaves, most of the perennials probably use water more efficiently than the broad-leafed annuals. But because they are green and using water for several months longer than the annuals, over years they might dry out soil and grow less. Here we breeders need help from agronomists: How much of a problem is this? Can it be managed with generous plant spacing, mowing or growing the plants among other species? Could plant breeding alter key aspects of perennial sunflowers' form, growth rate or timing to increase water efficiency?

Yields of sunflowers are high for a "minor" crop, but modest compared with major crops. The average sunflower yield in Kansas from 2000 to 2005 was 1,200 pounds per acre, though yields of 3,000 pounds are possible in good conditions. Compare this with the average yields of soybean and wheat: 1,760 pounds and 2,300 pounds per acre, respectively. On the other hand, for oil production it is hard to beat sunflower. Soybean seeds are less than 20 percent oil, sunflower seeds up to 50 percent.

If an annual sunflower crop can produce 600 pounds of oil per acre in 90 days, a perennial should be able to do the same plus other things in the more than 200 days it is photosynthesizing each year (in Kansas).

What are some of the other things that a perennial sunflower will be able to do with those 100 or so extra days worth of photosynthesis?

■ Keep a permanent root system to hold our precious topsoil.



At far left is the leaf of a crop sunflower. Just above it is one from a wild annual. The four narrow leaves at right are from wild perennials. Between are how some of our hybrid. Narrower leaves might use water more efficiently.

■ Maintain live growing points throughout the winter, probably at a fairly small cost to the plant.

■ Leak sugars from their roots to feed the soil community of microbes and small animals that play such an important role in cycling nutrients, building organic matter and keeping soil loose for air and water.

■ Produce large amounts of nectar and pollen. In my experience there are few plants that come close to supporting the numbers of beneficial arthropods, including bees, ladybugs, butterflies and spiders, that I always find living in my perennial sunflower experiments.

Oil sunflowers, with smaller, black seeds, yield slightly higher than the "confection" varieties, which have large kernels in easy-cracking gray or striped shells and are eaten directly. Ninety percent of the approximately 244,000 acres of sunflowers in Kansas is typically planted to the oilseed varieties. This reflects the growing appeal of sunflower oil as a healthful and high quality cooking oil. It has high levels of vitamin E, no trans fats, low levels of saturated fats, mild color and flavor, and a high smoke point. The oil in some new sunflower varieties is similar in composition to olive oil: more than 80 percent monounsaturated.

The Land Institute's mission is to breed and promote perennial grain crops to replace today's annual grains. More than 80 percent of the world's cropland is planted to grains, a category that includes cereals like wheat and rice; pulses, including beans and lentils; and oilseeds, such as sunflower and rapeseed. Vegetable oils have become essential in most world cuisines. Like starchy foods, edible oils are an excellent source of energy. And there are two forms of fatty acids that, like vitamins, the human body cannot synthesize, and must obtain by eating plant oil or animal fat. Eating foods with oil or fat also helps the body absorb fat-soluble nutrients such as beta-carotene. For these reasons the World Health Organization recommends that 15-35 percent of a person's calories come from oils and fats.

I have been trying to make the case that oilseeds are an important part of The Land Institute's goal of basing the human diet on perennial plants. The case is even stronger if we consider needs other than food. In the coming age of petroleum scarcity, plant oils will be needed for fuels like biodiesel, and polymers for adhesives, paint, plastic, etc. Even in a nonindustrial future, vegetable oils might be called upon to replace traditional resources: Going back to whale spermaceti for lamps, bear grease for soap, mink oil for waterproofing or even hardwoods for heating and cooking will not be possible in a world with at least 8 billion people.

We are fortunate that sunflower oil is healthful and tasty. We do not know what oil from perennial sunflowers will taste like, but I have nibbled on wild seeds and not noticed strong or unpleasant flavors. Sunflower geneticists think wild species might have genes to improve annual sunflower oil's fatty acid profile for both nutrition and industry.

Production and Uses of Sunflower

Globally, sunflowers are the fourth most important oil crop (Chart 1). Most of the sunflower seed crop is crushed for oil, and most of the oil is for human consumption (Chart 2). A major byproduct of crushing is protein-rich cake, an excellent feed for livestock. A small part of the global sunflower crop is directly eaten by humans as "nuts" or kernels.

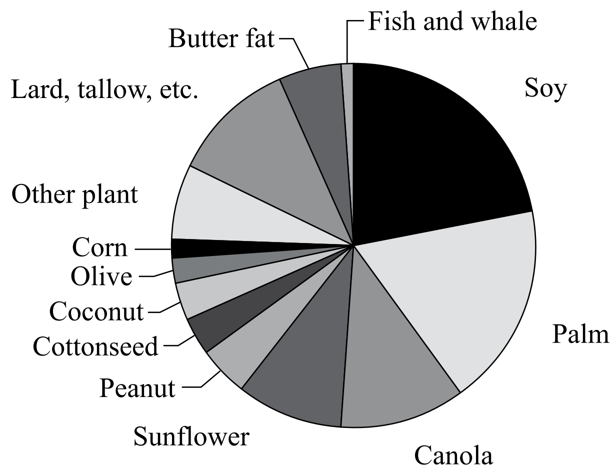


Chart 1: Global production by weight of animal and plant oils (U.N. Food and Agriculture Organization data for 2005)

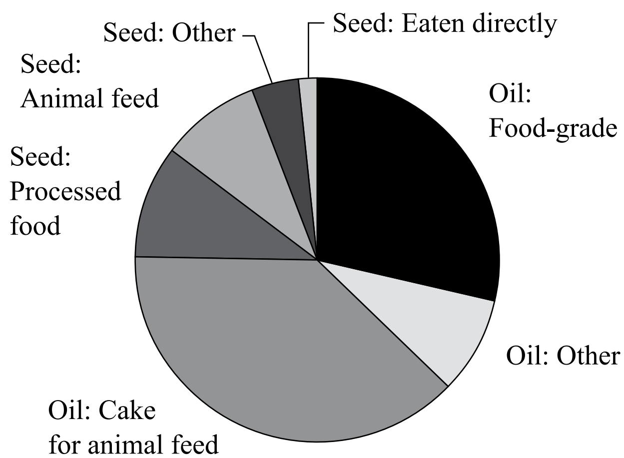


Chart 2: Global consumption by weight of sunflower products (U.N. FAO data for 1996)

So what is our strategy for reinventing the sunflower? One is to breed annual crop plants with wild perennials and select offspring that combine high yield with pereniality. The other is to identify promising wild perennial species and domesticate them from scratch. We are focusing on two wild species. One is Maximilian sunflower, a true sunflower from the genus *Helianthus.* The other I call Kansas rosinseed, a sunflowerlike species from a different genus, *Silphium,* in the sunflower family. While this path takes no advantage of "yield genes" concentrated in annual crop sunflowers by earlier breeders, it might be the faster strategy. Not crossing the species boundary eliminates the problems of "mules": infertility due to chromosome mismatching and/or stunted growth due to other genetic incompatibilities. Additionally, these species are already adapted to local soils and climate, and to life without fertilizer.

We have pursued cross-breeding of different species since 2001. For the first couple of years I learned, mostly by trial and error, about the mechanics and genetics of crossing sunflowers. Hybrids between Maximilian sunflower and crop sunflower were very rare, and even then dead-ends, producing no pollen or seeds. But other breeders had used chemicals to artificially double the numbers of chromosomes, restoring fertility by guaranteeing that all chromosomes could form matching pairs. In 2002, C. C. Jan of the U.S. Agriculture Department's sunflower research group in Fargo, North Dakota, kindly gave me several hybrids between crop and wild perennial sunflowers. I crossed these and grew out several hundred plants. A few proved to be true perennials. Land Institute co-worker Sheila Cox and I did our best to save every seed of these rare plants for planting next year.

The literature describes crosses between Jerusalem artichoke, *Helianthus tuberosus* and many other species of sunflower, annual and perennial. This tuber-producing perennial sunflower is a hexaploid—a species naturally containing six copies of all chromosomes instead of the two copies found in most other sunflower species. Bread wheat is also a hexaploid, and like the hexaploid sunflowers it is relatively easy to cross with other species. Less so are the two-copy, diploid, species, which include humans and crop sunflower. I was further inspired by the many vigorous

Sheila Cox plucks anthers from a crop sunflower to keep it from making pollen. Only the female parts of the head's flowers remain fertile. We leave the heads of other plants unscathed but bagged to collect the pollen instead of letting it be carried willy-nilly by insects. Then we can brush the pollen from one particular plant on the emasculated head of another, even of a different species, aiming to combine the best traits of each.

hybrids made this way by Brent Hulke and Kevin Betts at the University of Minnesota. Since 2004, Cox and I have made hundreds of crosses between Jerusalem artichoke and various diploids: modern varieties of crop sunflower, wild annuals, Maximilian sunflower and other perennials.

The hybrids are presumed to be tetraploids; they should have three sets of chromosomes from the hexaploid perennial and one set from the diploid annual, though we have not done the microscopy to confirm this. With an even number of sets of chromosomes, pairing is possible. And indeed we have seen some pollen produced, although the amount of pollen and seed is smaller than it would be in one of the parent species, because the chromosomes are from different species and don't always pair properly. We also have made crosses using a different hexaploid perennial, *Helianthus rigidus*.

Although these wild hexaploid species are true perennials, my goal has been to use them as a genetic bridge between annuals, including the crop sunflower, and perennials, many of them drought tolerant—Jerusalem artichoke is not.

In addition to making new crosses between the species, Cox and I are crossing hybrids with hybrids. In this way we create plants that have genes from three or even four species. Although all of the hybrids are assumed to be tetraploids, with four copies of all chromosomes, as are Jan's hybrids, we do not know if all of the hybrids will be able to cross with each other. We may end up dividing our hybrids into several groups, called populations, in which the members are able to cross.

I want to develop populations with as many combinations of the most extreme traits as possible. No one has a clear idea of what a high-yielding perennial sunflower will look like. I mentioned the problem of perennials declining in yield and vigor over years. Could it be that as a seedling becomes a clump and a clump becomes a patch, its stalks come to compete with each other and not just other individuals or other species? To avoid this, should we breed the rhizomes—the underground stems from which new shoots emerge— to be more spreading or less? To reduce moisture depletion under a clump of perennial sunflowers, should we breed them to have many stalks with narrow leaves or a few stalks with broad leaves? Do birds get more seeds from many smaller heads or fewer larger heads? What traits make a plant neighborly if it is grown in mixtures with other crops—are they different from what makes a plant less competitive with its own siblings? Our new populations have genes for all of these traits and many others. By growing out large numbers we should be able to find individuals with almost any combination.

More than 50 of our hybrids known to include genes from crop sunflower survived the winter of 2005-06. They are very diverse in height, flowering time, seed size, head size, flower color and leaf shape and size. This year we crossed them with each other and with other hybrids, and saved seeds to be planted next year. In 2007 we will be able to do a comprehensive evaluation and select promising families and individuals.

In our direct domestication of two wild perennials, we are further along with Maximilian sunflower. In 2000 we collected seeds from more than 100 locations in Kansas to ensure a starting population with lots of genetic diversity. From study over four years, I identified the 20 plants with the highest combined scores for seed yield, seed size and shatter resistance. In 2006 we bagged them, to keep out the bees and the pollen they bring, and breed them using each other's pollen. Next we will study about 2,000 prog-

A Native Gets Culture Abroad

Though Native Americans domesticated sunflower, early European settlers seem to have been much more interested in corn. Sunflowers were brought back to Europe in the 1500s, but remained an ornamental or novelty crop until 1760, when an English patent was filed for pressing oil from the seeds. By the 1830s, according to the American Sunflower Association, commercial sunflower oil production began in Russia. This might have been because the Russian Orthodox Church bans many traditional oils and fats during Lent, but the novel sunflower was not on the blacklist. Russia is still the world's largest producer of sunflowers.

German and Dutch Mennonite farmers were invited to farm in Russia in the late 1700s. Their descendents moved in the late 1800s to North America, bringing "Russian Mammoth" sunflowers with them; U.S. seed catalogs began offering Russian Mammoth to gardeners in 1880. At the farm scale, initial interest was for chopping the leaves and giant stalks and fermenting them as winter livestock feed; Minnesota researchers bred "Arrowhead" from Russian Mammoth in 1920 for this purpose. The first North American grain sunflower breeding program began in Canada in the 1930s. The first U.S. variety developed for seed production, from the heirloom variety "Mennonite," was Mingren, released in Minnesota in 1964. Formal Russian sunflower breeding had begun in 1912, by V. S. Pustovoit, the first scientific sunflower breeder. The International Sunflower Association awards the Pustovoit prize every four years.

Commercial sunflower acreage spread in Canada and the Dakotas, especially after the importation of new Russian varieties in the 1960s. Perhaps the development of modern sunflower in the cool climate of Russia explains its early success in Canada and the northern Great Plains. North Dakota, South Dakota and Kansas, in that order, are the top three sunflower growing states.

eny. The best of these will be crossed with each other. This cycle will be repeated many times.

The Land Institute identified Maximilian sunflower as a possible perennial grain candidate years ago. The sunflowerlike genus *Silphium* drew us more recently. We noticed that several of its species seem extremely drought tolerant and have very large seeds, though fewer than in Maximilian heads. I collected seeds from the two most common species in Kansas and grew out rows of plants from each collection in 2003. I found that the compassplant, *S. laciniatum*, grew very slowly. I later learned that other people have reported that it takes up to 25 years for this species to flower. The other species, *S. integrifolium,* which I call Kansas rosinseed, though it has no common name, established easily and flowered vigorously in the second year. It appears to be much easier to grow, and more suited to cropping than compass plant. Subsequent work has focused on it.

In 2004 I harvested seeds from natural crosses between the plants in my nursery and planted them early in spring 2005—they require several weeks of cold and wet to germinate. This year these 50,000 or so plants flowered for the first time. Summer research assistants and I identified 80 plants with unusually large numbers of seeds. This is easy in the genus, because only the florets around the edge of the heads—the ones producing the showy yellow "petals"—set seed. All we had to do was count petals. Cox and I crossed these plants. In addition, I saved seed from 200 other plants that produced many heads, large seeds or interesting traits such as being short but productive. Some of these traits are bound to be influenced by patchiness in soil fertility and moisture, but next year we will plant these seeds in a new experiment designed to better identify genetically superior plants.

Our perennial sunflower program seems pretty predictable for at least the next dozen years: cycles of selection and cross-pollination of selected plants. In each cycle we aim to eliminate genes that lead to low yield, competition between plants or unsynchronized growth. By starting off with a broad genetic base, we hope that diversity of all other kinds of genes will be preserved.

In the meantime, we will encourage geneticists and plant breeders elsewhere to start their own perennial sunflower programs. We watch with interest the work of the University of Minnesota's Don Wyse and his graduate student Brent Hulke, a Land Institute graduate research fellow. Like us they have developed perennial hybrids by crossing crop sunflower with Jerusalem artichoke. Unlike us, they are trying to cross the hybrids back to the crop sunflower to rapidly increase the proportion of genes from the domestic plant. This strategy is more likely to make a perennial sunflower that looks like traditional crop sunflower, while ours is more likely to make plants quite distinct from it. We support each other's work however we can, knowing that every independent program and strategy increases the odds of developing high yielding perennial crops.

Plant breeders are notoriously optimistic, expecting next year's populations to be "the best yet." In that tradition, I hope that within a few years we or the University of Minnesota will have breeding populations with full fertility, but also somewhat tamed, that we can offer to ecologists and agronomists. We will need their help answering many questions about plant spacing in the field, nitrogen transfer from legumes to sunflowers, planting among other crops, and weed and insect management. Other studies might help us document the presumed benefits of perennial sunflowers. Can farmers expect to use these crops to help improve soil health, water quality and populations of "natural enemies"—spiders and insects that prey on plant pests?

My colleague Lee DeHaan, who works with wheat and the perennial intermediate wheatgrass, says that a field of mature sunflowers has a melancholy look: They are old men, heads hung in grief or resignation, pondering the dust to which they will shortly return. I say they are just mystified, looking in vain for their missing rhizomes. The rhizomes got left behind millions of years ago when the annual sunflowers broke from their perennial ancestors to make a living playing fast and loose in disturbed soil. We are going to get them their rhizomes back … and quit disturbing the soil so much.

At left is a confection variety of crop sunflower, with big seeds for eatin[g] is Silphium integrifolium, *a perennial wild plant in the sunflower famil[y]*

The Hybrid Question

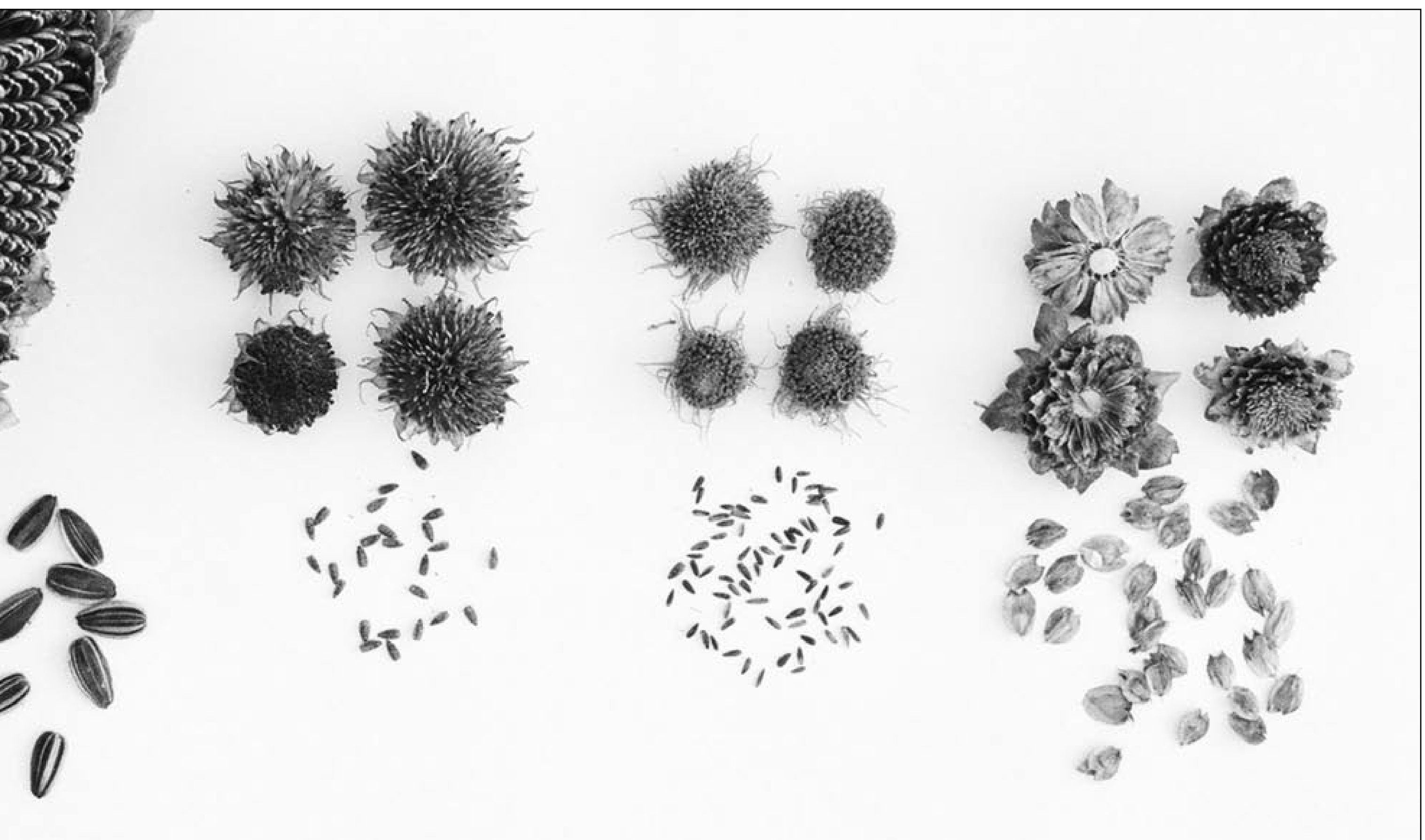
Government-funded breeders in Canada began working on sunflower in the 1930s. A sunflower seed crushing plant was built in 1947, and production spread from the prairie provinces into North Dakota and farther south in the Great Plains. The United States now produces 10 times more sunflower seed than Canada, but has seen only one new registered variety since 1970. Have U.S. breeders been asleep or snubbing this crop?

Publicly funded breeders register their varieties in the journal *Crop Science* and make them available to anyone willing to produce and sell certified seed. More than 500 varieties of wheat have been registered in the United States since 1970. Soybean and alfalfa breeders also register their varieties, churning out 408 and 158 respectively since 1970. Yet corn, the number one crop in the United States, with over 11 trillion bushels produced each year, has only one registered variety.

Modern sunflower and corn breeders don't make varieties: They breed inbred lines used to make hybrids. Public breeders register and share their inbred lines, but these days most lines are bred by private companies. Private breeders legally protect or even patent their lines, but do not share them.

Defined broadly, hybrids are the seeds produced when one type of plant is pollinated by another type. The two types can be different-looking plants, plants from different varieties, or even plants from different species. Most of these kinds of plant hybrids are made by researchers only in the first stage of the breeding process. The exception is hybridization used to make what are called, variously, "F_1-hybrid seed," "hybrid varieties," or—most often and least precisely—just "hybrids." Allowing many plants from two uniform, inbred varieties to cross-pollinate is the only way to produce the millions of hybrid seeds needed for commercial production.

Many plants primarily pollinate themselves. Not corn and sunflower, which, though capable of self-pollinating, use wind or insects to carry pollen from plant to plant. If corn plants undergo inbreeding through self- or sibling-pollination, vigor and yields decline. Similar things happen



g. (Most crop sunflower is for making oil.) Next is a wild annual sunflower, then the wild perennial Maximilian sunflower. At far right y with larger seeds. We're working to domesticate the two wild perennials.

when human societies inbreed. But in crop plants, inbreeding also has advantages. It is the simplest way to make crop varieties that are uniform in height and growth rate.

In the early 1900s there was little progress against inbreeding's yield depression. Hybrid corn, which became widely available in the 1930s, solved the problem: Two strategically chosen inbred varieties were crossed, instantly reversing genetic inbreeding to dramatically increase yield and produce seeds that were almost genetically identical, very uniform and predictable in their growth.

Hybrid varieties do not breed true: Their seeds are perfect for eating but undesirable for producing a new crop, because every offspring of a hybrid plant is genetically different from every other. Seed companies make fresh hybrid seed every year from their protected parent lines, but this means farmers must buy new seed every year. Indeed, that guaranteed sale is the main incentive for the company to make hybrids. Within 20 years of the introduction of commercial corn hybrids, most corn farmers in the United States were planting only store-bought hybrid varieties.

As the science of genetics matured, breeders realized that high-yielding open-pollinated—nonhybrid—varieties of corn and sunflower would have been possible. With careful breeding, open-pollinated varieties could be made more uniform without harmful levels of inbreeding. Unfortunately, though we now know this, it would take decades of breeding to catch up to the yields of today's hybrid varieties. Furthermore, farmers in industrial countries have become accustomed to buying hybrid varieties of corn and sunflowers, and big seed companies have nothing to gain by moving toward varieties that farmers can save each year.

These days, farmers buy commercial, hybrid seed of some self-pollinating crops, such as grain sorghum, that could probably be bred and grown just as productively as nonhybrid varieties that don't require yearly seed purchase. To be fair, saving farm-grown seed isn't trivial. A farmer must clean it to eliminate weed seed and store it carefully to maintain good seed vigor. It's easier to buy the latest variety already cleaned, bagged and guaranteed. On the other hand, nonhybrid, public varieties of other crops are routinely grown and bagged commercially. They are more expensive for farmers than homegrown seed but less expensive than patented or hybrid varieties.

University and government breeders are reluctant to be seen as competing with seed companies by releasing new varieties when private, hybrid varieties are available. An independent organization like The Land Institute has the freedom to develop open-pollinated or hybrid varieties depending on the biology of the crop and the breeding objective. Either way, we are committed to public ownership of our varieties and the free exchange of plants and seeds between breeders. And buying perennial hybrid varieties wouldn't commit farmers to buying new seed every year. Perennial sunflower hybrids will continue to produce grain and maintain their hybrid qualities for many years before replanting is necessary.

Why Sunflowers Follow the Sun—and Other Pursuits

Do the heads of sunflowers really track the sun? Yes and no. They don't really rotate back and forth, as do some special organs on other plants. But the sun does influence the average direction that young heads point.

Like most plants, sunflowers' growing points, including buds, reach toward light to get as much as they can. You might have suddenly noticed a houseplant leaning toward the nearest window. How did that happen? The growing tips use the hormone auxin to stimulate cells on the dark side to grow faster.

During early summer sunflowers grow so quickly that the growing points change direction over the course of the day. The huge heads perched on the tops of the stems make these slight changes exaggerated and obvious to us. As stem growth slows, the heads swing less. When growth stops, the heads remain fixed in one direction.

Curiously, most sunflowers end facing east. There is no official explanation for this, but I have a couple of hypotheses.

The simplest is that plants facing east catch the first rays of the sun, and their glowing yellow petals catch the eyes of insects needed for pollination.

My other hypothesis is a bit more complicated. I have noticed that on cold, dewy mornings, pollen is shed later in the day than on warm mornings. Many plants delay pollen shedding until humidity levels drop. Dampened pollen quickly dies. (We plant breeders use this to our advantage when removing the male parts of sunflower heads before controlled fertilization with pollen from another plant. We spray the heads to kill any pollen we missed.) I think sunflower heads facing early light should dry sooner and therefore gain a jump on neighbors in releasing pollen and attracting insects to spread it.

Whether facing east attracts insects with pollen or with color, the result would be the same: There must be some competitive advantage to being among the first to draw insects. Could it be that often there are not enough insects for complete pollination? This can be true in commercial orchards. However, I've rarely found sunflower pollen except on heads that are bagged to catch it and let us control pollination. This suggests that visiting insects are quite thorough. Wild sunflowers simply swarm with insects when they are flowering.

I also almost never find stigmas left unpollinated each day—easy to tell because they shrivel within hours of pollination but otherwise stay healthy for days. And seed formation in unbagged heads nears 100 percent. I don't think that risk of missing pollination can explain the apparent race for insect attention in the morning.

Another possibility is that the first plants visited by bees will be more likely to father seeds both on other early plants and on plants visited later in the day. Assuming bees don't as often visit flowers where pollen has already been harvested, later-shedding plants will pollinate fewer flowers than early-shedding ones.

One more benefit for early-rising plants would be if there is a race between different kinds of pollinators. Pollen is nutritious, and many arthropods depend on it. Some, like bees, flies, moths and butterflies, are fast and mobile. Flitting from flower to flower, they are ideal pollinators. Beetles, on the other hand, might eat a lot of pollen, but spend most of their time moving from head to head on a single plant. From the plant's perspective, they would be poor pollinators. It would pay to attract bees and butterflies early.

Here is the circumstantial evidence for this in sunflowers. First, there is the expensive investment in huge yellow petals and nectar. There must be competition for the attention of insects that navigate visually and move from plant to plant. The petals advertise a free meal of sweet nectar.

Second, like almost all plants, sunflowers make far more pollen than is needed to pollinate the stigmas. Plants compete to pass on their genes by trying to father as many seeds as possible. Fathering a seed passes on the same number of genes as mothering them, but costs only the price of a few grains of pollen, while mothering a seed requires filling it with costly food—oil in sunflowers.

I see this as a pollen arms race: The only way to compete with other plants producing excessive quantities of pollen is to produce just as much … or more. Competing to deliver the pollen quickly might be as important as producing vast quantities of it, just as having fast, dependable ballistic missiles is as strategic as having mountains of nuclear bombs.

In summary, my best guess is that sunflowers face east during pollination because facing any other way would put them at a tiny disadvantage in the race to father as many of the year's crop of seeds as possible. That is my best guess and it seems like a testable hypothesis. I could grow sunflowers with an obvious trait—like black seed hulls—in large pots. At the time of pollination I would move these pots to a field of white-seeded sunflowers. I would scatter the pots throughout the field with some potted plants facing east and others facing west. The next year I would grow out the seed harvested from plants neighboring each pot to see how many of their seeds had been fathered by the potted plants. Did the east-facing plants manage to father more seeds than plants facing other directions? Would pulling off the sun-catching petals or preventing the morning warming by shading the plants negate the benefit of facing east? Here are some excellent science fair projects! Let me know what you find out.

The arms race to produce pollen has done nothing to help sunflowers produce more seeds or adapt to their physical environment. I will refrain from making additional analogies with human arms races, but point out that competition almost certainly deprives a plant of resources that could be used to make more or bigger seeds.

Breeders have deliberately selected for plants that are less competitive in height. (This is discussed more in the main story.) And whether deliberately or unconsciously, selection for higher seed yields has sometimes given us varieties that make less pollen. Modern corn varieties usually have fewer, smaller pollen-producing tassels than do old varieties.

Whether arms races are beneficial or not is a matter of perspective. While we consider any arms race that cuts into seed production to be wasteful, to bees there is nothing wasteful about overproduction of pollen. They might see plant breeders as unconscionable agitators, egging on plants to make more seeds than could ever possibly germinate and grow to maturity.

Big yellow petals help attract the bee to nectar and pollen from the sunflower head's scores of little flowers. Dusty pollen on the bee then gets a ride to fertilize other plants.

Our Barn Spilleth Over

Hundreds fill the barn and ground around it to hear the Prairie Festival's closing talk Oct. 8, by Land Institute President Wes Jackson.

For more on the festival, see the next three pages. Dennis Dimick photo montage.

What Draws Them

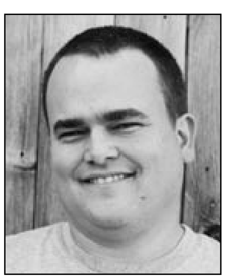
We wondered at the record number—more than 800—who overflowed our barn for the Prairie Festival Oct. 6-8. Ken Warren, The Land Institute's managing director and the festival's main organizer and promoter, said he needed to figure out what he did wrong.

Really, we are grateful. This annual event on our grounds outside Salina, Kansas, is a lot of work for us, but to see the faces of supporters from around the continent, to be with kindred spirits in our work to develop perennial grain crops out of caring for land and country—it is wonderful.

We asked folks why they came. Here are some of their answers.

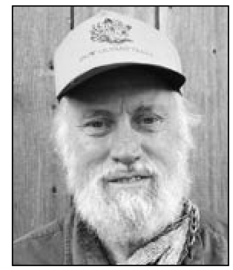
Bruce Johnson, from Bennet, Nebraska, and who teaches environment and resource economics in the agriculture department of the University of Nebraska: It's the coming together of people that are engaged. And, quite honestly, a lot of times you don't see that engagement—you see people with ideas, but they're not putting them to work. And I've always appreciated that this is hands-on, this is applied work here. And the people you bring in are making a difference by applying it. … I saw a big van from Iowa State sitting there, and thought, next year, I'm going to get some students out here, whether there's a formal thing in terms of sustainable ag or what, we're going to make sure there's vans running from the University of Nebraska down here. … It's so much more invigorating than me going back and telling them.

Jane Talkington, who is studying at Oklahoma State University, in Stillwater, for a doctorate in sustainability: I came because sustainability is such a broad field and I don't have a lot of experience in sustainable agriculture. I wanted to learn about people who were pioneering the effort.

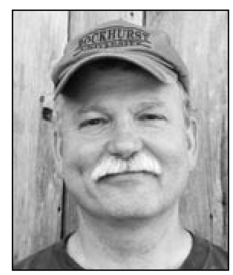


James Branum, of Oklahoma City: Four or five years ago, when I was searching for meaning in my life, I read Wendell Berry for the first time, and it really changed the way I saw things. …When I heard that he was going to be here, I wanted to get to see him. Also, I've read Wes Jackson's stuff, and what The Land Institute does. … And also to get to hang out with friends.

Barbara Schwering, an occupational therapist from Lawrence, Kansas: The first draw was to hear Wendell Berry—that was what caught my eye. But we haven't been here for a while. We used to come, in the old days, where we had potluck dinners and we camped. And now our children are gone, and we decided to come out for a weekend in this beautiful environment and to see what was going on out here, because we follow the work in the newsletter.



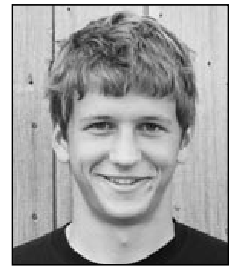
Dick Andrus, who teaches environmental studies at Binghamton University in Binghamton, New York: I've known about the place for quite a while; probably back in the '80s is when I first found out about it. But one of my students was an intern here back in the early '90s and that's what got me out here the first time. … To me it's like you've died and gone to heaven when you come out here and meet people and talk to people like Wendell. … To most people, they're just pictures on book covers; here, they're real people.



Randy Schwering, Lawrence, teaches at Rockhurst University in Kansas City, Missouri: I'm a business professor, and I frankly feel a calling to send this message we just heard to the business community, because without that kind of change, we're doomed. [Referring to a talk by carpet manufacturer Ray Anderson about making businesses environmentally responsible and sustainable.] I learn a lot by coming to these. It's possible for business and industry to transform itself—it can be done. It can be done profitably. And it can be done in a way where ultimately we work toward sustainability. I sense that there are increasing numbers of people who realize that we are not on a sustainable path at this point, and that, again, business and industry have to play a key role in this. And the message here today is a very uplifting one. To me that's one of the real challenges in the environmental movement. … I asked a class the other evening, one class with a group of MBA students, and we went into a lot of these same kinds of issues. And there was this incredible blank look on everybody's face, and I just stopped the whole class. And I said, "What's happening to you people?" … Normally the class is talking and very animated and back and forth. … And basically their thing is, "First of all, we hadn't ever really thought about this issue of the responsibility that business has to the environment," which shocked me, A. But the second thing is, "What can we do? We feel overwhelmed by the challenge before us, and it just seems so large that we can't succeed with that." Again, Ray's message is so important right now, because it says that it can be done. It can be done. That's so powerful. It is a moral responsibility on my part to put myself in a circumstance where I learn about such things and do whatever I can to forward that agenda.

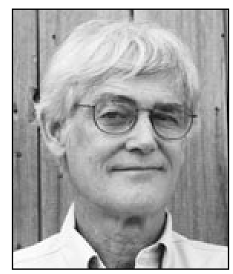
Gerry Craig, a Kansas native now of Sylvan Lake, Michigan, and assistant director of Cranbrook Art Academy: "The speaker lineup—Wendell Berry, Ray Anderson—and I hadn't ever been to it, and I was really intrigued with being here, to see what The Land Institute does. I'm a real environmentalist. In my art jobs I've tried to attract people to sustainability issues like green building, and build awareness to the public through great art and design. I was a curator at the zoo, teaching people to fall in love with nature through art and theater. I'm green to the core. I found out about The Land Institute by looking for writers, and doing Internet research, saw the Prairie Writers Circle. Janet Kauffman, one of the Prairie writers, is coming to lecture at Cranbrook this year, on big agriculture." [Prairie Writers Circle is The Land Institute's program to produce and distribute essays about topics including agriculture, ecology and community.]

Mike Callicrate, a rancher and farmer in St. Francis, Kansas: I come to the Prairie Festival to connect with other people, people who have a deep understanding of the whole issue of food—where it comes from, how it's processed, distributed and delivered to people. And how that can really somehow make a difference in the environment, in the sustainability of our system in agriculture. … Ray Anderson—wow: Here's a guy that actually made the possibility of doing something significant and doing something good also profitable. And that helps. If what we propose actually makes money, then we can implement it much, much faster. I've got a company called Ranch Foods Direct, and I'm opposing the Tyson's and the ConAgras, and the big Cargill companies, and trying to offer consumers a better product. … I come here to try to figure out what other people are doing. What are you doing that's working, and how might I learn something like Ray? What is he doing, and how is he doing it? His talk was very interesting to me. I just want to be able to make a difference in the problems I've been handed, and try to solve my piece of getting good beef to consumers. I just see that it's going to take some serious predator control. … That's where, like they say here at this meeting, we have to become political. We have to get our people elected that understand these issues, and can help us achieve a better alternative.



Brian Mikinski, a senior at Salina's Central High School: I really feel it's a great message that we're talking about. … And I like to learn about what's going on here. … Something this good is going on in the community—I want to know about it. My biology teacher told me about this.

Leesa Schmidt, who is studying English education and special education at Dordt College, in Sioux Center, Iowa: My major actually has nothing to do with agriculture. I'm really interested in this kind of stuff and wanted to broaden my knowledge as to what's going on, see what could be done and what is being done.



Dennis Bramble, of Salt Lake City and a University of Utah biology professor: I heard one of Wes Jackson's inspirational talks at the University of Utah about 10 years ago, and so I became a contributor to The Land Institute, and I've always wanted to get here for one of these festivals. But my teaching commitments have kept me away. This is the first year when our fall break coincided with the Prairie Festival, so I jumped at the chance. I'm also involved in a restoration project on the Colorado plateau—rangeland restoration—so I'm interested in range use history, people's connection to the land, and also rejuvenating beat-up land. I figured there'd be plenty of people around here who share those interests.

Rachel Jackson, of Oklahoma City: I'm looking very intentionally for a way to be more comprehensively free and ethical … and I think the ideas and methods of living that The Land Institute promotes and studies are the best way that I've found to see those things. … The closer I can be to people who are trying to follow that road, the stronger I'll be in my own journey.

For recordings of festival speeches, turn the page.

Prairie Festival Recordings

October 6-8, 2006, The Land Institute

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Long View, Lost Chance

An e-mail solicitation and response at The Land Institute in May 2001.

Regarding the commercialization/rapid adoption of Land Institute research and discoveries: John and I are with the Enron Xcelerator, a new business unit whose charter is to create new businesses. We are not restricted to the financial, energy and information fields exclusively (Enron's current venues). John and I are specifically interested in natural systems agriculture. We are interested in your discoveries thus far and would like to open up a dialogue between our respective organizations.

In addition, [Land Institute General Manager] Ken Warren's eclectic background in biology and geology combined with practical financial experience is in line with John's and my background that led us to Xcelerator (John—civil engineering with financial experience, myself—mechanical engineering with risk management and financial experience). We believe that the three of us can weave a common tapestry of natural systems agriculture, financial derivatives and risk management.

Here's Enron Xcelerator's mission statement:

"To treat innovation as a commercial activity, creating and commercially proving a new series of businesses that can grow to become Enron's next core business model through a dynamic mixture of talent, network and capital resources."

In short, if we don't do it at Enron yet, we will.

John Nixon, director
Joe Phelan, senior director
Enron Xcelerator

Where I am always open to new (for us) avenues of capital, as is any hand-to-mouth entity, I would hasten to point out that we may not be the ideal candidate for your consideration.

The reason for this is multifold:

First, at this point of our life we do not have nor are we close to a marketable product. Our product, when available, may be both tangible (plants, germplasm, etc.) and intangible (methodologies to quickly establish natural systems agriculture).

Second, the time frame in which a plant breeding-based system operates is by nature (no pun intended) long. The program we have mapped has a 25-year timeline.

Third, the methods we use are those of traditional plant breeding and, while we are not totally opposed to biotechnology, we are guarded in its use—we have ruled out transgenics at this point.

Fourth and probably most important for you, if we were to develop any patentable product, it is our intent to keep same in the public sector.

I applaud your interest in natural systems agriculture, as current industrial food growing systems have left soils eroded, surface and groundwater polluted or just plain used up, and several dozen harmful (to humans, etc.) chemicals floating in the food, air and water—not a great legacy for future generations.

Sincerely yours,
Ken Warren
The Land Institute

Thanks for the response. I understand. Yet I am disappointed that your efforts will have such a long time horizon. There will be a lot of damage done in the next 25 years. I can't help but wonder if there is a place for a financially minded company like Enron to alter the agricultural space the same way we did in energy.

In the old days, inefficiency was rampant, assets stranded, and energy supply was a local monopoly. Now, thanks in part to Enron, power can be provisioned more efficiently on demand. Even sulfur emissions can be traded and managed via free market mechanisms.

I can't help but wonder what the state of agriculture would be like if the power of the free market was unleashed to manage nitrogen pollution, phosphorous, pesticides, etc. In such a world, organic farming and perennial agriculture would generate immediate and significant earnings in the form of publicly tradable derivatives. Sustainable farming would be profitable right out of the gate, instead of 25 years from now. Imagine the income statement of a local organic farmer including CO_2 credits, nitrogen credits, soil erosion credits, etc., all monetized in real time making his farm wildly profitable.

Anyhow, if you see a shorter term opportunity, please keep the Enron Xcelerator in mind. Otherwise, I'll see you in 25 years. Don't be surprised to find the financial derivatives required to maximize the value of your products already in place.

Best regards,
Joe Phelan
John Nixon
Enron Xcelerator

The Dust Storm

Lois Phillips Hudson

Two springs ago, according to local newspapers and to coughing, red-eyed service-station operators in the Rocky Mountains, we drove through the worst dust storm Wyoming had suffered in 18 years. The wind was prematurely aging the young Rockies, pushing dusty fingers under the loosening fragments of thin topsoil that covered the grazing plateaus, picking up the small greenish gravel from the road shoulders, and hurling dust and gravel into the air at 60 miles an hour. If we dipped into a trough between plateaus, its shelter enabled us to see the laden wind rising over the mountains and the sky running in massive dirty currents above us. After reaching the Coast we replaced the badly pitted window glass, had the car repainted, and cleaned the seats, floor mats and window crevices. Yet months after we thought we had breathed the last Wyoming grit, we turned on the defroster and blew bits of the Rocky Mountains all through the car.

Dust storms are like that: No matter how many times you clean or how much you scrub and repaint and dig into crevices, you are always finding another niche the dust has found. And in the dust is the smell of mortality, of fertility swept away and spring vanished.

For me the storm was the revival of the nightmares of childhood, and I breathed again the dust of the storms that drove my family from our North Dakota farm. I remember particularly the storm of the spring when I was in the second grade. That morning in late March the sky had the kind of height that only the sky of a prairie or a desert or a sea can have; it makes its own boundaries, its symmetry never spiked by the reaching of tall trees, never crowded by the peaks of mountains. It was the kind of blue that can come only from the cleansing of melted snow.

But now, after the earth had softened for a few days and allowed the great banks of snow to sink into her embrace, seemingly chilled by her own compliance, she had hardened again. For a week now, the plowed furrows had been so full of frost that we could walk them as if they were railroad tracks. Gone were the rivulets bearing the snowbanks out into the fields where the fetal leaves sprang forth, marvelously green in the rich black mud. This usually happened, of course; you could expect an early thaw to be followed by a hard freeze. Even so, those first days of fast melting, with their joyous profusion of water, were enough to instill in the most drought-embittered farmer the resolution to try one more crop before he got out.

The ambition nourished by that first thawing sent the farmers out to get in a few days of early plowing, to burn away the thistles collected against the fences, to oil machinery that may have sat under 6 feet of snow all winter, or just to tramp over their land to check the depth of the moisture and to visualize the August fields. On this morning my father planned to mend fences, and as he piled his heavy ancient equipment into the rear seat of our 1929 Ford he sang one of his favorite songs, *The Bulldog on the Bank and the Bullfrog in the Pool*. He was singing because perhaps this year there would be no drought, and perhaps our share-the-crop landlord, who ran a clothing store 20 miles away, would let him plant the way he wanted to plant—not insisting on having the entire crop be soil-depleting wheat—and perhaps the prices would go up enough next fall so that he could buy a secondhand tractor and retire our worn-out team. It was not often that he sang, and I felt good hearing him, because I thought the three-mile ride to school would not be as silent and austere as it usually was.

My mother pushed me out the door after one last "No" to my whinings about taking off my winter underwear. As soon as I felt the wind, I had to admit to myself that I was glad I had lost the argument. This argument was mostly a ritual anyway, to demonstrate my confidence in spring.

On this day, even though I knew the wind meant another month in long underwear, I was happy, because a really hard wind was a wondrous playmate. My mother had shown me how to raise my coat at arm's length over my head and, holding the two corners of it, let the wind fill it and send me sailing along like an iceboat. She had often told me of ice-boating on Lake Michigan when she taught school there in the years before the Depression, and for some reason the only clear ideas I had about how life would be "when good times come again" were all tied up with iceboating. Except for that, the idea of "good times" was very dim to me, despite my parents' efforts to explain it in material terms: oranges every day, new coats instead of garments pieced together from the least worn parts of discarded adults' coats, a car that was maybe only about 2 or 3 years old, for the advent of streamlining had humiliatingly outdated our square old Model A. The thought of being able to visit our relatives in Michigan and go iceboating was the clearest conception I had of good times; surely this was the sort of exhilaration we would all feel every day when good times came again.

There was a good chance that the wind might provide some real excitement that day, it seemed to me. As we drove through the stubble fields of our farm, a miniature whirlwind misted up from the dry ruts of the road, spun toward us, and broke itself against the car in a small fury of powdered earth, pebbles and straw. My father sneezed and jerked the car around a rock in the road.

"Do you think there will be a hard wind today?" I asked, trying not to sound too eager and to make dignified conversation about the weather the way grownups did and thus sound interesting to my father. (He always told me not to talk unless I could say something interesting, but I could never figure out just which of my ideas were interesting.)

"*You'd* be happy if it blew 90 miles an hour, wouldn't you?" was his only answer. His light mood was gone already and we weren't even on the main road yet. I was quiet the rest of the way to school.

In school I stared out over the heads of the first-graders from my desk in the middle row of the three-grade room and watched the wind. I could see the Koslovs' washing hung in their back yard. Trouser legs bestrode the air, and Old Man Koslov's big-bellied underwear bent double-jointed knees and elbows in drunken imitation of its hard-drinking owner. I looked at Ivan Koslov to see if he was aware that the whole primary room was grinning over his grandfather's underwear, but he was lost in a discouraged slump over his reading book. My father had told me that all the Russians ("Roosians," he called them) were dumb, because they plowed up the land in the fall so the wind could blow it over everybody else's land all through the winter and spring, and they didn't know how to farm to keep the fertility in the soil, and, worst of all, they wouldn't even bother to learn the English language. This last I knew was true; the parents of many of my Russian schoolmates still didn't speak English even though they had lived in North Dakota for many years. It never occurred to me at the time that Ivan and the others might have some excuse for their difficulty with reading. All I knew was that reading class was pretty boring and that it was a relief when the recess bell rang.

At recess, when there wasn't too much snow, we used to play a game called anty-eye-over, using the roof of a long low appendage to the main building. In this game the players on one side throw the ball over to their opponents, yelling "Anty-eye-over!" as a signal that it is coming. If the receivers catch the ball, they try to surprise the other team by sneaking around the building and capturing players by hitting them with the ball. The teams took up their positions on either side of a narrow shed covering two separate hallways that led to the two separate little rooms with their four bitterly cold board seats over the trench below, into which the janitor dumped enough lye to half suffocate the users of the rooms. Most of the length of the shed was for the obvious purpose of removing the toilets as far as possible from the classrooms, and so it provided a generous space for our game. On this day, though, the wind did such ridiculous things with the ball that we had to give up and play the wind's games. We used our coats for sails or experimented with nonchalant off-balance poses leaning into the wind.

In the Koslovs' field behind the school, last year's dead tumbleweeds (we called them Russian thistles) unwound their roots from the disintegrating earth and came sweeping erratically across the ground at us. We played a tense game of tag with these brown stinging monsters, the tangible claws of the unseen wind, the articulation of its anger. They would hook into each other and roll in a dragging bumping wave till they caught in a fence.

By noon the whirlwinds were everywhere and had dried up the surface of the fields. The whirlwinds rushed across the playground sucking up lunch bags, old papers and caps of children trying to eat their lunches outside. I was fast losing my enthusiasm for this wind. Only last summer a big tornado had passed less than 10 miles south of us. We had all gone down into the storm cellar to wait for it to come and pull our house up into its widening funnel. It had spared us, but the cloudburst that went with it had not. Yet the things the tornado did to other people made us ashamed to complain about the ruin we suffered from the cloudburst.

I was through with this wind as a playmate. The sky was already dim with dust and the dirt was splatting into my eyes and mouth. I went back into the schoolroom and watched Ivan Koslov and his sister Neva and some of the others eating apples. They all got boxes of apples from the relief. "Why don't *you* go on relief?" they asked me. I didn't answer them. My mother had told me we were too proud to be on relief. My father had gone to apply for a WPA job on the highway once, but the administrator had asked him to say that we were even poorer than we were, and he wouldn't lie. He knew most of the others had lied to get their jobs, but he would have starved rather than resort to a "Roosian trick." So I was really proud that we didn't have apples.

I turned away from the feast and got a book to read. It was a book of fairy tales, and in the corner of a map on the endpapers was a supposedly whimsical depiction of the North Wind. He had a fat dissipated face with billowy cheeks, and his eyes glittered greedily under the icicled eyebrows. By the time lunch hour was over the sounds of the god's hunger and of his reverberating digestion were too much for the teacher to talk above, and she let all three grades have an unprecedented extra art period. But even the luxury of cutting colored paper and making clay animals did not relieve our tension. We feared daytime darkness as savages do, knowing that the earth's disasters were our own.

By 4 o'clock, dismissal time, there was a besieged line of vehicles outside the school gates. Most of the men were in open wagons, as was my father, because very few people could afford buggies, and practically all of the cars in that area were, like ours, too vulnerable to trust to such weather.

Some of the men were standing on the lee side of their horses, like Arabs in a sandstorm—but not my father. He wouldn't ask a horse to take anything he wouldn't take. He sat on the plank thrown across the sides of the wagon box, the bill of his earmuffed hunting cap slanting over his eyes and the collar of his sheepskin coat hunched up along the back of his neck. He had done what he could for the horses; there were old blankets over their backs under the harness and feed bags up over their nostrils for dust filters.

Before I had got a foot on the hub of the wheel, which I used as a step, my father reached down his gloved hand and jerked me up into the wagon. Although we usually sat apart—I often in the back hanging my legs over the flapping tail-gate—this time he pulled me hard against him to give me all the protection he could. He wrapped a heavy cowhide around me, draping its tannery-smelling stiffness over my head, with the dusty tickling hairs touching my cheek. Each vehicle in turn detached itself from the group, leaving the illusion of solidarity for the reality of solitude in the shrieking storm. The 3 miles home took us almost two hours.

Usually on my return from school my mother would welcome me with some casual questions about what I had done that day. But now she kept her face turned away from me and greeted me with an order to wash and pour some milk. I went to the small wooden box under the window-sill where we kept the Mason jars full of whole milk we saved out before running the rest of the milking through the cream separator. We kept the box there because so much cold air came in around the window in winter.

As I bent to pick up the milk I noticed the damp rags that were stuffed into the cracks between the window frame and the sash and along the sills. They were black with dust.

"Boy, there's a lot of dirt here!" I said.

My mother didn't look up from the stove. "That's not the only place there's a lot of dirt." Only twice before had her voice sounded like that—once when my grandfather died and once when I accidentally broke the only window in our dark little kitchen. Terrified, I stared about me and saw that the dust was sifting down everywhere.

The kitchen was actually a lean-to addition to the other two rooms in the house, and keeping it livable was a losing battle but one that my parents never gave up. Once a year in the spring, before outdoor work began, and when no more melting snow could seep down from the roof and stain the walls, we spent the money for paint. It was the cheapest calcimine available, but things did look much better for a while, and the annual refurbishing of the kitchen was a kind of treat for us.

Inspired by the thaw, we had painted just after the last snow stain had dried in the plaster. Along with the farmers who had planted too early, we had been too ambitious, too eager for spring. Now this house that my mother was always so ashamed of would bear the depressing murkiness of the storm all year long. There would be summer days when the thermometer read 100 degrees outside, and yet she would have to build a fire in the coal stove to heat the water for washing and heating the sadirons. There would be the months of dim winter when the sun rose long cold hours after we did and set again in a frozen peach-colored sky hours before supper-time. And through all those days she would look up from her iron or her washboard or her kneading or her nightly mending by the kerosene lamp to behold those foul darkening streaks on the walls that contained all of her life—all of it that was not spent outside toiling in whatever black earth remained to us.

In that same awful voice she broke out, "Oh, what's the use of trying!"

If she was going to cry, then here indeed was the end of hope—things could only get worse, always and always worse.

The next morning the sky was very blue again, in the way it has of being especially blue just after storms. My father had gone looking for the stock. The dust, catching in the Russian thistles that were clinging to the fences, had packed so hard and piled so high in several sheltered areas that the cattle and horses had walked right up the dirt banks and over the fence.

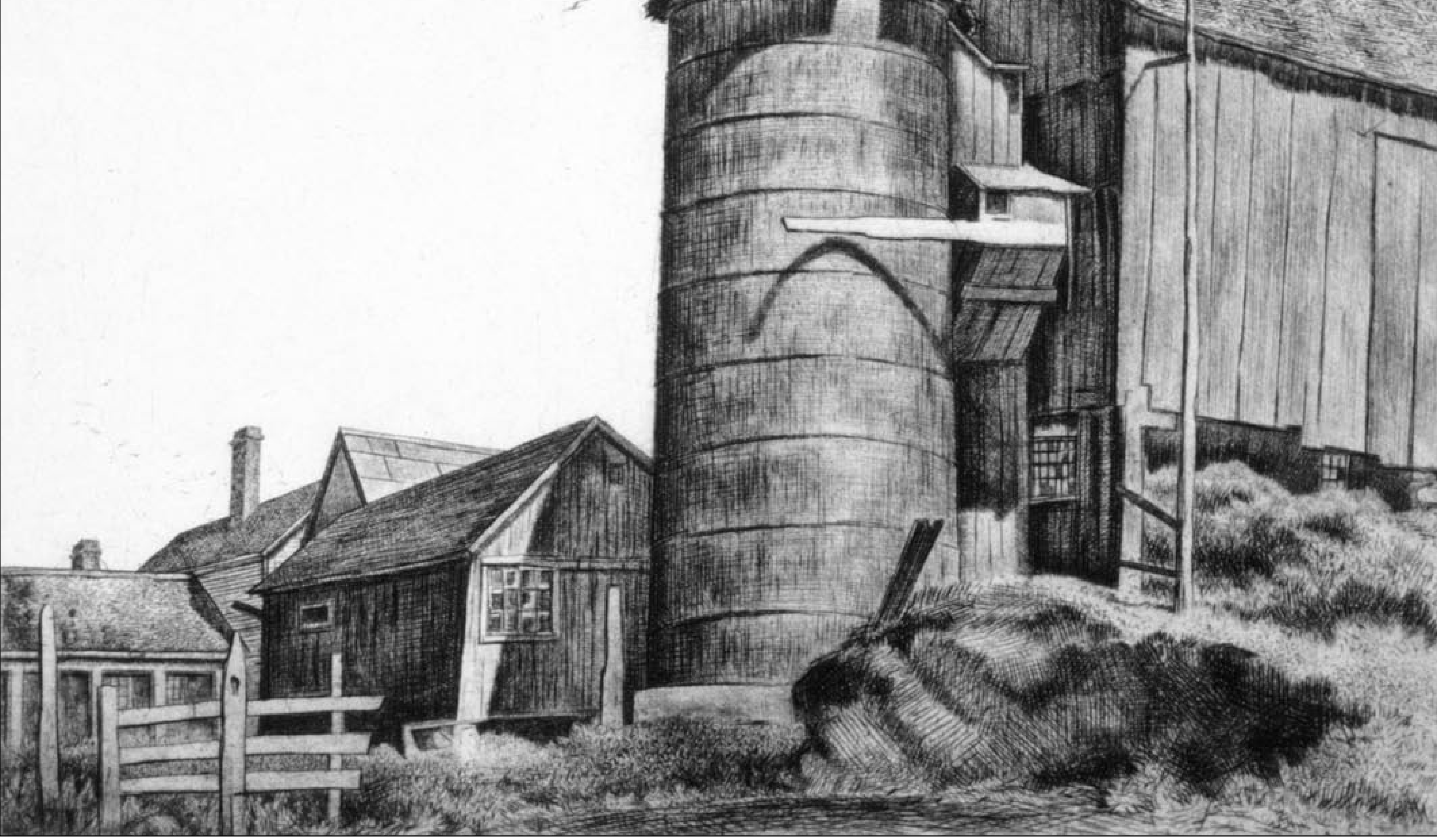
Once, in the memory of my own grandparents, that atomized earth had been nearly impossible to break with a plow. Enriched by the floods of vanished rivers, the droppings and bones of numberless generations of buffalo, the mulch of thousands of summers of grass, it waited now, an unsalvageable encumbrance upon the sagging fence—waited to be carried farther and farther, scalding other fields in its passing, finally coming to its grave in the Mississippi Delta. There was no rain to hold it for us, no rain to nourish clutching roots before the next wind.

A prairie child, walking in the loneliness of great spaces, absorbs familiarity with eternity. In that enduring loneliness I might have existed through centuries of freedom and bounty, when the grass rose to the shoulders of the buffalo and the grass and the buffalo fed each other, and the land and the grass held each other against wind and drought. This eternity of abundance had spread a feast for the bread-hungry world and for the soul of the farmer—but the farmer's soul had been too small to cherish the immense heritage.

Through the storm I was being informed that this eternity could not survive the ignorance of men. I was learning why my father sorrowed for the land, angrily grinding the dust in his teeth and thinking of the impossible combination of men and elements he faced—the illiterate "Roosians," the exploiting farmers, their exploiting absentee landlords, the wind, the drought. No dust storms began on his farm, but once the wind was full of dust his farm suffered along with the rest.

While I was eating my oatmeal the morning after the storm, my mother said, "Oh, I just feel so sorry for Daddy. He worked all morning in that wind yesterday on the north fence." This was all she said about the storm.

My father came in to take me to school. He didn't even say whether he had managed to round up the stock. A wind too big to allow communication was still all around us and inside of us.



Corban's Silo, *by Armin Landeck. Drypoint, 9.7 by 7.9 inches, 1937. From the collection of Steven Schmidt.*

We Need and Owe Rural People

Richard Manning

Kenya's Masai people, herders to the core, have found they can increase their meager income by leasing land to onion farmers. The farmers build fences, which dice up elephant migration corridors surrounding the country's famous Amboseli National Park. So wildlife groups have devised a novel system of payments to the Masai that cover the income difference between grazing and leasing.

The Panama Canal is in serious trouble, from obsolescence and because deforestation has altered freshwater flows and increased sedimentation. So major shippers like Wal-Mart, which gets about 40 percent of its merchandise through the canal, have purchased business-interruption insurance with whopping premiums. Understanding this, visionary Brazilian capitalist John Forgach bought land around the canal and pays poor rural people to plant trees and husband the resulting forest. Sedimentation is less, and freshwater flows more dependable. Shippers agreed to fund Forgach's work with some of their savings from reduced insurance costs.

Faced with a federal order to build an $8 billion plant to further purify its water, the city of New York instead, after pressure from environmentalists, tackled the problem's source: upstream farming and forestry practices, and real-estate development in the Catskill and Delaware river basins. About $2 billion to buy buffer zones and pay landowners for improved practices staved off need for the plant.

These are but three examples of recognizing something long invisible to the market's invisible hand: Rural land and rural people do a lot more than grow food or timber. Keeping rural people in place and doing good work tangibly and economically benefits all of us. By paying them to simply grow food or timber, the market greatly undervalues these people.

Intact wetlands filter water and control floods. Native grasslands and forests stop erosion and pull globe-warming carbon dioxide from the atmosphere. Preserved rural landscapes recharge the visiting city dweller, and they enrich our lives by helping us understand the link between land and food. Soundly managed rural lands are our most important source of wildlife habitat, especially in Midwestern and Eastern states with little public land. Healthy rural communities with proper amenities can stem the urban immigration now choking our planet's megacities.

All of these very real economic benefits are what economists call "externalities," meaning they are outside the market. We who benefit do not pay, which is precisely why these amenities are disappearing. If the market—pushed by government subsidies—will only pay a farmer to plant corn and soybeans fencerow to fencerow, that is exactly what will happen.

Or at least that is what happened until a handful of clever people around the world began pioneering ways to bring these services into the market—which is to say, to stop undervaluing rural people.

Ironically, the United States already pays enormous sums to supposedly support rural people. We spend well more than $20 billion a year in farm subsidies to encourage farmers to practice the most environmentally and socially damaging forms of agriculture. This significant social commitment does very little to support the diverse array of services we want and need. Mostly it supports large corporate farms to grow a handful of commodities—corn, wheat, rice and cotton—that are already in surplus.

The emerging work worldwide in payments for environmental services offers promising direction on how we might rework America's farm policy to reflect the real value of land and people.

With Prairie Writers Circle, The Land Institute invites and distributes essays to about 500 newspapers and a dozen Web services. All essays are at www.landinstitute.org and free to use.

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Where Is She Now?

Suprabha Seshan, a Land Institute intern in 1992, this year won a British conservation award worth about $55,000 for her protection and propagation of rare Indian plants.

Seshan, affectionately known here as Supi, directs the Gurukula Botanical Sanctuary in southwest India. She received a prize of the Whitley Fund for Nature, whose annual awards go to conservation leaders in research and protection that involves local communities.

The sanctuary is an area of southwest India where 10 percent of original forest remains, half of its native plant species are used for the world medical market and 20 percent face possible extinction within 20 years. Seshan works with trained local women on what she calls "ecosystem gardening," propagating and reseeding native plants, and enlisting villagers and farmers to reintroduce species to degraded places.

Seshan wrote to Land Institute President Wes Jackson, "I just wanted to tell you that somehow the Land is connected to all this, and that my year there and all that I learned remain precious to me. I've tried to follow through those important concepts within the Indian context: gardening in nature's image, reconstructing the structure and diversity of the forest as a means of habitat restoration and plant conservation. In fact, the very fact that I came here directly from the Land, to join this tiny endeavor in a remote part of southern India, is indicative that I had picked up another important message: Find one's place and dig in!"

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The Writers and Artists

Birger Sandzen, 1871-1954, came as a young man from Sweden, to Bethany College in Lindsborg, Kansas, and ended up staying. A namesake gallery in Lindsborg shows his work and that of modern artists.

David Van Tassel is a Land Institute scientist whose focus is breeding sunflower.

Dennis Dimick is a magazine editor and on the University of Missouri journalism school's faculty for Missouri Photo Workshop, which teaches documentary photography.

Lois Phillips Hudson wrote *The Bones of Plenty*, a novel about farm families in the Depression. The story here is from her collection *Reapers of the Dust: A Prairie Chronicle*. She lives in Redmond, Washington.

Armin Landeck (1905-1984) was a printmaker in New York City and northwest Connecticut.

Richard Manning, of Missoula, Mont., is the author of several books, most recently *Against the Grain: How Agriculture Has Hijacked Civilization.*

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The Prairie Festival barn dance, October 6. Dennis Dimick photo.

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