LAND REPORT

THE LAND INSTITUTE · SUMMER 2010

THE LAND INSTITUTE

MISSION STATEMENT

When people, land and community are as one, all three members prosper; when they relate not as members but as competing interests, all three are exploited. By consulting nature as the source and measure of that membership, The Land Institute seeks to develop an agriculture that will save soil from being lost or poisoned, while promoting a community life at once prosperous and enduring.

OUR WORK

Thousands of new perennial grain plants live year-round at The Land Institute, prototypes we developed in pursuit of a new agriculture that mimics natural ecosystems. Grown in polycultures, perennial crops require less fertilizer, herbicide and pesticide. Their root systems are massive. They manage water better, exchange nutrients more efficiently and hold soil against the erosion of water and wind. This strengthens the plants' resilience to weather extremes, and restores the soil's capacity to hold carbon. Our aim is to make conservation a consequence, not a casualty, of agricultural production.

LAND REPORT

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ELECTRONIC MEDIA

To receive Scoop, e-mail news about The Land Institute, write to Joan Jackson at olsen@landinstitute.org, or call. Our Web site is landinstitute.org.

SUPPORT

To help The Land Institute, see the contribution form on the back cover, or contribute online at landinstitute.org. Funders receive the Land Report.

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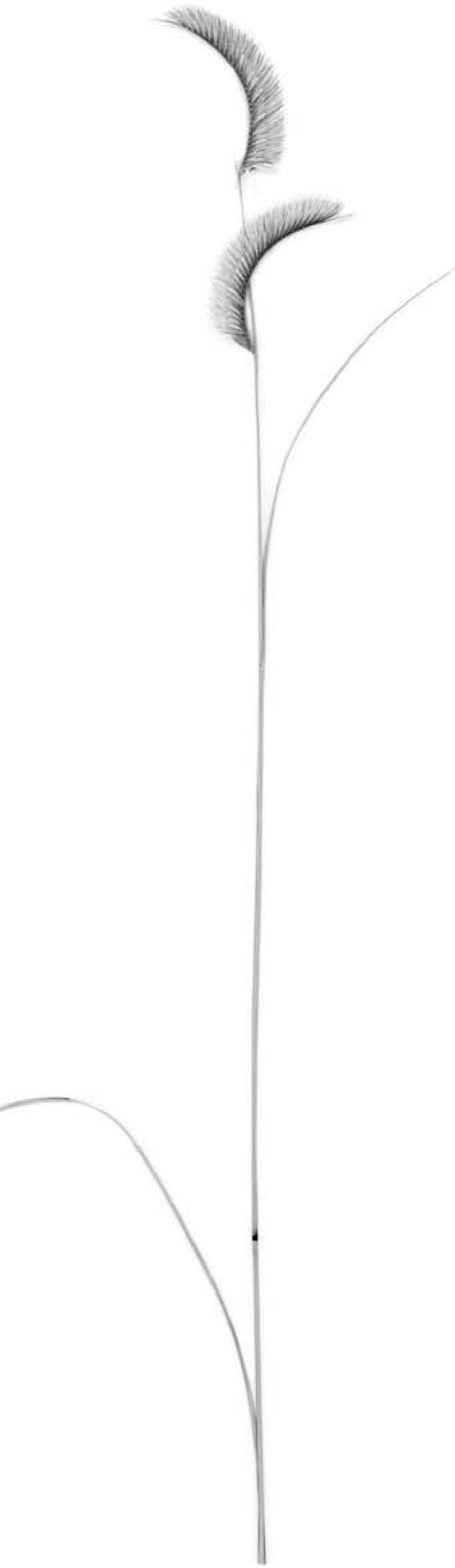

CONTENTS

LAND REPORT 97, SUMMER 2010

Cover and contents pictures by Matilda Essig. The cover is sideoats grama (Bouteloua curtipendula), August 3, 2008, Elgin, Arizona. The contents is blue grama (Bouteloua gracilis), October 3, 2007, Elgin. Both are grasses of Arizona's Apache Highlands. Essig will show at the Prairie Festival. *See page 22.*

At the Land

IN THE ANNALS OF SCIENCE

Science magazine, one of the two most respected science journals in the world, gave two pages in its Policy Forum for Land Institute researchers and 22 collaborators around the world to advance the need and means for developing perennial grains. We hope the recognition spreads public and scientific interest and policy-making for development of perennial grains. The lead author was our Jerry Glover. Other contributors were from across the United States and in China, Argentina, Australia, Mexico, and Sweden. The essay appeared in Science's June 25 edition. It is also at landinstitute.org, under Publications, Science.

TO THOSE WHO WAIT – AND REACH

Land Institute plant breeder Lee DeHaan had almost written off an experimental planting at another farm with ground so poor that he said, "The weeds hardly grow out there." Yields of annual wheat remain less than a fourth of the norm for Kansas, at about 10 bushels per acre. But after three years, the perennial-crop candidates intermediate wheatgrass and Maximilian sunflower have taken off. Apparently it took time for their roots to work through the red clay for deeply buried deposits of rich soil, which will remain beyond the reach of annual wheat. Now Maximilian plants grow 10 feet tall. DeHaan wants to study the site more, but sees a good case for developing perennial grains, particularly for land marginal but cropped by farmers without fertilizers.

WORK IN WASHINGTON

Land Institute soil scientist and agroecologist Jerry Glover is among 14 people around the world honored by National Geographic, in its June issue, as "inspiring adventurers, scientists, photographers, and storytellers making a significant contribution to world knowledge through exploration while still early in their careers." You can read more at landinstitute.org. Glover next will serve a year as science adviser to the US Agency for International Development. He'll start work in Washington on September 1. With him will be his wife, Cindy Cox, The Land Institute's plant pathologist, nematologist, and analyst of plant hybrid chromosomes. To learn how Glover helped build the case for perennial grain crops with a five-year study comparing the soils and yields of native prairies and adjacent wheat fields, see page 7.

ON THE HIGH ROAD

Land Institute board member Donald Worster, a historian at the University of Kansas, won the Scottish Book of the Year award for his biography of Scottish emigre John Muir, "A Passion for Nature." In his thank you note to congratulations from The Land Institute and board members, Worster wrote, "I am enjoying immensely my brief moment of being the most famous 'Scottish author' who is really not Scottish."

WHAT YOU DON'T KNOW CAN GUIDE YOU

A Land Institute conference in 2004 explored an "ignorance-based worldview," and from that, four years later, came an essay collection called "The Virtues of Ignorance." Now Land Institute collaborator R. Eugene Turner has introduced the idea to a professional science journal. The Louisiana State University scientist writes in Volume 32 of Estuaries and Coasts of how "can-do" land use in the Mississippi Delta brought catastrophic wetland loss, yet restoration work continues with the same confidence that knowledge already at hand will work for managing something vast and complex. He offers the following general suggestions:

- Assume that key information is not known and might never be known.
- Be flexible in how to gather and apply new information, and in evolving context.
- Include many small steps that are addressed many ways.
- Let data trump concepts, not the reverse – don't make the model too abstract.
- Expect surprises.
- Plan for how to reverse course and to exit.
- Do no harm: don't implement plans that will be irreversible if they go awry, and if irreversible outcomes are possible, start with the smallest plans, not the largest.

PRESENTATIONS

Land Institute staff members spoke at conferences and colleges in Illinois, Utah, Michigan, Ohio, Oklahoma, North Carolina, Massachusetts, Oregon, and the District of Columbia. Upcoming: August 15-17, Johnston, Iowa. October 23, Montana, exact location not yet known. October 25, Powell, Wyoming. November 7 or 8, Louisville, Kentucky. November 9, Wolf Lake, Indiana. November 10, Bloomington, Indiana. For more, call us or see Calendar at landinstitute.org.

In July workers were finishing sheetrock, installing wires, and painting The Land Institute's new research center. We'll dedicate it September 25 at the Prairie Festival. Improvements have begun on our greenhouse. The campaign to pay for these projects continues. Scott Bontz photo.

WORKS LONGER, WASTES LESS, NEEDS NO SUBSIDY

SCOTT BONTZ

In the summer of 1996, after months of inquiry, Land Institute intern Jerry Glover found a rare native prairie on rich bottomland. He'd sought it for comparing soil under the effects of agriculture with that of a natural ecosystem, the institute's model for a new kind of agriculture. But when he arrived at this vestige amid wheat fields a county away, Glover recognized more than just a chance to study soils. The prairie had been mowed, and it bore half-ton bales of hay. Glover, farm-raised and curious, put pencil to back of envelope. And his reckoning showed the meadow yielded as much protein-building nitrogen as the surrounding, fertilized wheat.

How could unfertilized, wild vegetation match a crop bred for production and receiving 60 pounds of synthetic nitrogen per acre each year? How could prairie do this after seeing its prime green growth shorn and carted off each year for most of a century? Glover and other scientists can't fully say. But they see a strong connection with the prairie's complex underground economy. It is an economy possible only where plants haven't quit and gone before a year is up. Glover concluded that this means achieving sustainable agriculture will never come merely by conversion from conventional to organic methods, but only by conversion of the plants themselves – by making grain crops perennial.

"That was an awakening for me," he said of that summer day 14 years ago. After his internship he took back to Washington State University the idea born of his calculations, and instead of just finishing his bachelor's degree, was inspired to earn a doctorate in soil science. When he returned to work at the institute in 2002, he also returned to that prairie, to look deeper.

He'd originally been assigned to compare the soil effects of organic and conventional methods, at The Land Institute's 72-acre farm on prime river valley land. But if the institute's model for farming was natural ecosystems, Glover thought, shouldn't he compare the crop ground, whether organic and conventional, with the soil of native prairie, the dominant natural vegetation of central Kansas?

Many papers already told how prairie soils are more fertile than soils under annual crops. Glover didn't want simply to say

At left: prairie's perennials and superior soil equal wheat at production of protein-building nitrogen, but without the annual crop's fertilizer subsidy. Land Institute scientist Jerry Glover says this shows why humanity must develop perennial grains to achieve an agriculture that can be called sustainable. Jim Richardson photo.

again, "Prairie soils are better." He wanted to show with some precision how they are made better. And he'd never actually studied the differences himself: "I really wanted to see side-by-side how they compared. I wanted to get beyond a literature review."

To do this fairly he sought prairie on a floodplain soil like that at the farm, not thinner upland soil. He wanted to give annual crops their best shot. But upland is where lay all native prairie remnants he could see around the institute. Farmers had plowed out the Smoky Hill River valley's good ground a century earlier. Still, Glover hoped to find a pocket of bottomland soil, and after many phone calls, he did.

It was near a place called Niles. A railroad and waterway bisected and bordered the 20-acre pocket. This hindered repeat passages by the machinery required for annual crops – tilling, planting, cultivation, harvest – especially when the area's first farmers decided what to grow where, and used horses, which in harness abreast don't turn as easily as tractor or combine.

Glover took to Niles a hollow steel tube called a corer, drove it 4 feet into the soil and pulled out samples. He'd done the same at The Land Institute farm. There, cores matched description of their soil type in a soil science book – like plants and animals, soils have taxonomy. Also matching were samples from the wheat fields abutting the Niles prairie. But not the prairie cores. Rather than clump in hand, they crumbled, a sign of life therein. And reaching much deeper in the ground was the rich, dark color of high soil organic matter. Glover first thought the soils map must be wrong, the prairie earth of a different type. But he said, "It was just that the native prairie had maintained very different soil characteristics." Same soil to start with, diverging human history.

That history of agriculture is one of removing nutrients from landscape. Sometimes nutrients and sediment are replenished by the like of floods, sometimes they are not. Over time, in most places, agriculture has proven a net loss. Barring subsidy that eventually means less food. Between the decades of 1875-84 and 1915-24, despite improved varieties Kansas corn yields fell by half.

Now we cover for soil mining with fertilizer. This we mine from shrinking reserves of phosphorus and potassium, or synthesize from atmospheric nitrogen with mined fossil fuel. We practice life support, not maintenance of healthily living soil.

Healthy soil – sustainably productive soil – is indeed alive, a hidden metropolis of fungi, worms, bacteria, and other microbes. The plants on which we depend most directly are just one niche of the market. Healthy soil has not only that biological community, but good chemistry and good physical structure. It must begin with the right proportion of sand, silt, and clay. It needs enough chemical nutrients to support the organisms. These and their products all bind the mineral particles for the structure of organic matter to soak up and hold more air and water. From this plants benefit, and pay back the other soil life with sugars for energy and other organic carbon for building. It's all a complex and unbeatably efficient arrangement, and one that works best without intervention.

Scientists detailed this in five years of study at Niles and four more sites that Glover found scattered among as many counties – rare, irregular niches of native prairie amid wheat fields sharing the same valley soils. The work, which involved samples from the prairies and Agriculture Department records for wheat in the same counties, also supported Glover's initial reckoning of equal nitrogen yields despite wheat's annual fertilizer subsidy. And hay took less than one-tenth of wheat's energy bill, two-thirds of which went to that fertilizer.

Nitrogen is the most common element in the atmosphere, but also the hardest for plants to get in usable form, and the hardest nutrient to keep in the field – beyond which, in groundwater, stream, and sea, it becomes pollution. And more than with any other nutrient, plant production swings on nitrogen. Looking the other direction: if a field is yielding lots of nitrogen, Glover said, things are likely OK with the other nutrients too. This is one reason why he chose nitrogen as the gauge to compare the prairie hay and wheat yields.

Another is nitrogen being a principal component of proteins. In hay, it builds cattle. In wheat it builds us. Nitrogen is the fourth most abundant element in the human body. That nitrogen of our flesh and bones comes from the atmosphere and the soil only via plants. "They are the primary producers," Glover said.

Wheat takes more land than any other human food. And wheat yields in central Kansas are just 7 percent more than the global average. Glover said these two things help make The Land Institute study a robust representative for what a difference could be made by changing agriculture from dependence on annual grains to reliance on perennials grown more like in natural ecosystems. (For more about why grains are annuals, though need not be, see page 14.)

Exactly how perennial plants can match annuals that enjoy a huge nitrogen subsidy lies still somewhat veiled in the folds of the perennials' roots and attendant life. But it's clear that prairie soil food webs are better sponges. They soak up nutrients in times of excess and slowly release them to plants in times of need. More roots and more diversity and abundance of soil organisms make for greater efficiency and conservation. Wheat might let slip past almost half of the nitrogen coming from farmers. The same is true for other annual crops. Their roots are shorter, shorter-lived, or both.

The want of annual crops is not just in size, but in timing. Steve Culman, who was a Land Institute graduate studies fellow at Cornell University and participated in the study, said tillage exposes soil to air, and then molecular reactions release a huge flush of nutrients. Tillage comes before the plant, however, and without roots at the ready for sopping those benefits, there's waste. Farmers compensate with fertilizer. This is often impractical to apply in several little doses, mimicking the slow release from decomposition and fixation in prairie, so they give it all at once, and there is further waste. Perennials don't enjoy the benefits of tillage, and prairie hay fields typically don't enjoy fertilizer. But come spring and the first green, their massive roots are up and running.

In terms of that timing, the advantage over annuals is huge. But even after growing up, wheat lags badly. At Niles, root mass in the prairie was 6.7 times greater and roots 3 feet deeper than in the adjacent wheat. Worldwide study of temperate grasslands, dominated by perennials, found more than nine times the root mass of croplands. (To learn how perennials can outgrow annuals aboveground, see page 18.)

That greater size and longevity pumps down and leaks more nutrients to soil organisms, which in turn keep the soil better for the plants. Glover said that if plants provide more growth above ground and below, over a longer stretch of the year, it should follow that they support a more complex,

John Mai readies for analyses soil samples taken from native prairie and neighboring wheat. Scott Bontz photo.

efficient, niche-filling, and productive food web. Roots supply up to 80 percent of the carbon stored in soil ecosystems.

The carbon in soil makes microbe bodies, waits in the dead cells of plants for decomposition and reuse, and binds tightly with soil particles. It is the main part of the No. 1 indicator of soil fertility: organic matter. More carbon can help soils better hold water and keep nutrients and sediments from running off, which both make for cleaner water. Carbon also can make soils more stable, less vulnerable to erosion. Organic matter involves acids that make minerals available to plants. In The Land Institute study, for both organic carbon and organic matter in the upper 16 inches of soil, where lies most of wheat's root mass, the amount in perennial hay fields was greater by 40 percent.

That upper prairie soil also was 12 percent less dense, and a third higher in what soil scientists call water stable aggregates, which make for porous but sturdy latticework to better admit roots, air, and water, and better hold the water. Culman said, "A good topsoil is crumbly and light."

The ability of grasslands to equal a fertilized annual grain crop is not just because the plants reach deeper through that honeycomb, but because the soil courses with that underground economy. How much plants can produce depends not just on how much carbon, nitrogen, phosphorus, and 14 other essential elements make the soil, but on how well and quickly worms, arthropods, and microbes eat the roots, litter, and excreta left after harvest or grazing, and recast the ingredients for cementing and firing again with gases from the air. Soil organisms do all this for themselves, Culman said, but in doing so benefit the plants that feed them: "They rely on these microbes to continually stir this pot of nutrients." Glover said the structure and character of the soil food web strongly affect that recycling. Undisturbed and well fed, the web can be stable and efficient. Disrupted and left wanting, it can quickly start to fade.

The soil community barometer for the study was nematodes, tiny worms. There are thousands of species, and one ounce of soil can harbor 2,800 individuals. They are diverse niche-fillers: parasites, herbivores – some of them crop wreckers – predators that eat the others, and omnivores. That's why they serve, like nitrogen does for other nutrients, as an indicator of a soil's biology in general. With another graduate fellow, Tianna DuPont, of the University of California at Davis, Culman found nematode communities a quarter to more than a third richer in prairie than in neighboring wheat. The prairie's nematodes had more predators and omnivores, which could reduce the amount of plant eaters. Regardless, because predators suffer more when disturbed, nematode scientists see them as signs of greater soil stability and health.

The prairie's richness in nematodes appeared to go strongly with the other gauges: nitrogen, root mass, organic matter, carbon in forms usable by soil organisms, the mass of those recycling microbes, and soil weight and structure. Whether this is cause and effect would take more study, Culman said. But he called differences in perennial and annual soil biology huge. The importance of nematodes to plant growth seemed clear enough for him to say, "I think you'd be hard-pressed to frame a counterargument to this – that they play no role at all." Culman now asks, "How can we apply that to agriculture?" He has moved on to compare, at Michigan State, the effects of annual wheat and perennial wheat.

DuPont, Culman, Glover, and the other scientists recognized that their study might be unfair to modern farming technique. The soil quality they were seeing in the wheat fields might be an artifact of inferior methods from decades ago. So they converted three small blocks of the Niles prairie to current annual grain cropping practice, with herbicides and no tillage, and watched how the soil changed in comparison with neighboring plots that continued under haying with no additives. Jim Duggan, the owner and a no-till farmer, was not only gracious, but curious. In just three years the converted plots' root mass was less than half that in bordering prairie. Apparently as a result, the nematode community fell, as did the amount of the readily oxidized carbon. Other carbon forms take longer to decline. Over the three years, conversion plot soil also kept good structure, an advantage of no-till. And the nematode and fallen carbon levels were still above those in the old wheat fields. But the study numbers solidly indicated a slide. Where they would bottom out will take more investigation.

Something that will remain unknowable with certainty is whether these Kansas prairies with so much more carbon and nitrogen than neighboring wheat fields still have as much as when haying began near a century ago. But studies elsewhere make it seem likely. Rothamsted Research in England has hayed unfertilized perennial grass plots twice a year for 150 years without a decline in yield, and with no fall in soil nitrogen since the ability to measure it was developed 120 years ago. For 50 years, unfertilized grassland hayed annually in a Russian study lost neither soil nitrogen nor organic carbon. Again, nitrogen is the main nutrient player in yield. So if soil nitrogen remains steady, Glover said, so should yield.

If the five Kansas prairie sites in his study are producing as well now as they did 75 years ago, then over that span they've outyielded the neighboring wheat fields by almost a quarter. Wheat farmers before World War II didn't have much fertilizer, or plants bred for taking loads of it, and yields were less than half what they are now. Breeding advances might prevent return to the prewar level. But if the supply of synthetic fertilizer falls with the supply of fossil fuel now used to make it, so will the yields of annual wheat, corn, and all other plants of the green revolution.

Nitrogen isn't everything. The Kansas hay fields are sending to livestock elsewhere crucial mineral elements like phosphorus. But their perennial roots continue to mine deep, parent material deposited by winds and rivers or developed from weathered bedrock. Some day, barring another ice age, volcanic eruption, or other geologic main event, what plants can make from this supply will decline, and with it, food production. But the natural slope will be imperceptibly slight compared with the plunge we face with annuals after cresting the summit of fossil fuel. The fall of perennial grassland yields, so far undetected, could be close to nil for hundreds of years.

Regardless, hay still won't feed humans, at least not directly. What could, and slow or stop decline of fields under annual crops, is return to perennial vegetation, only this time with plants bred to put more of their comparatively bountiful nitrogen and carbon into seed, just as our current grains were transformed from wild ancestors.

As Land Institute plant breeder Lee DeHaan has put it, farming method, such as organic or no-till, is like software. The change to perennial cropping would be like new hardware. Glover said, "We need new hardware."

The studies are under Publications at landinstitute.org.

FIELD NOTES

THE NATION BEHAVES WELL if it treats the natural resources as assets which it must turn over to the next generation increased, and not impaired, in value. – Theodore Roosevelt

THE SCALE OF HUMAN CIVILIZATION, the volume of our economic activity, and the power of science and technology have made us shapers of much of the earth. The power to shape leads inevitably to a responsibility to wield this power wisely and carefully. – Newt Gingrich, "Contract with the Earth"

WE'RE RAISING OUR CHILDREN on the definition of promiscuity if we feed them a casual, indiscriminate mingling of foods from every season plucked from the supermarket, ignoring how our sustenance is cheapened by wholesale desires. – Barbara Kingsolver, "Animal, Vegetable, Miracle: A Year of Food Life"

FOR GOD'S SAKE, be economical with your lamps and candles! Not a gallon you burn, but at least one drop of man's blood was spilled for it. – Herman Melville, "Moby-Dick"

ONE MAN CANNOT STOP the soil from blowing. But one man can start it. – Hugh Hammond Bennett, in Timothy Egan's "The Worst Hard Time"

[A] LOWER-IMPACT SOCIETY is the most impossible scenario for our future – except for all other conceivable scenarios. – Jared Diamond, "Collapse: How Societies Choose to Fail or Succeed"

EVERY COUNTRY can be said to have three forms of wealth: material, cultural, and biological. The first two we understand very well, because they are the substance of our everyday lives. Biological wealth is taken much less seriously. This is a serious strategic error, one that will be increasingly regretted as time passes. – E.O. Wilson

WE ARE *where* we are even more than what we eat. – Gregory Conniff, in the essay "Where Do You Love?"

WE MIGHT SEE fossil fuel as playing the same role that slaves played in early American agriculture – a "natural resource" that comes cheap. ... There aren't many people on that farm, but there's all kinds of machinery, and every bit of it is burning fuel. Here's the math: Between 1910 and 1983, US corn yields grew 346 percent. Energy consumption for agriculture increased 810 percent. – Bill McKibben, "Deep Economy"

IT IS DIFFICULT to get a man to understand something when his paycheck depends upon his not understanding it. – Upton Sinclair, "I, Candidate for Governor: And How I Got Licked"

IT TURNS OUT that the tiny effects that turn up always require the most revolutionary modification of ideas. – Richard P. Feynman, "The Meaning of It All"

Perennials such as apple trees can surpass annual grains in the proportion of their growth going to the parts we take to eat. Natural selection didn't favor this attractive development in perennials grasses and forbs. Modern plant breeding could. Here, Sheila Cox tends perennial sunflower seedlings at The Land Institute. Scott Bontz photo.

THE THIRD WAY

DAVID VAN TASSEL

Scientists concur that perennial grasses and other herbs – plants without wood – usually outperform annual crops at using soil moisture, harvesting sunlight, conserving soil, and providing wildlife habitat. The Land Institute and others advocate turning some of the more productive perennial herbs into grain crops, because most cropland is planted to grains.

This is where the consensus breaks down. Plant ecologists in the 1970s noticed that short-lived wild plants tend to invest a higher proportion of their energy into sexual reproduction than long-lived ones. It seemed that while annuals build flowers, pollen, fruit, and seeds, perennials build towering trunks, deep roots, spreading runners, thick bark, and other structures to compete with each other and survive the slings and arrows of outrageous weather.

This fits well with what we know about animals. Short-lived mice and rabbits compete to produce as many babies as quickly as possible. Long-lived moose and elephants sport enormous tusks or antlers for more direct competition between rivals, but take many years to reach reproductive – and competitive – size.

The idea of breeding lab mice for the size and strength of elephants but with the reproduction and docility of rabbits might seem ridiculous. That long-lived herbs with huge harvests of fruit or seeds never arose during millions of years of plant evolution, including 10,000 years of agriculture, is said by some to show that these traits cannot coexist, and that breeding for them would be ridiculous.

Lee DeHaan, Stan Cox, and I, The Land Institute's plant breeders, challenge the notion that longevity itself takes so much energy that seed production must necessarily be minimal. In a manuscript to be published in Evolutionary Applications, we note that the ratios of energy which some tree and palm crop plants devote to their fruits and seeds, including apples, at 65 percent, are the highest ever reported.

While the existence of oil-palm, olive, banana, and other long-lived plants that also invest heavily in nuts and fruits refutes the simple tradeoff of longevity versus reproduction, it raises a perplexing question. Why do farmers have many fruit or seed crops from the extremes of the land-plant world – long-lived trees and small, short-lived annual herbs – but not from plants intermediate for lifespan, size, or both – the perennial herbs?

The literature suggests that when humans began tending plants, two very different domestication courses naturally followed, and these two paths favored the two extreme growth forms.

Very large, long-lived plants could easily be propagated by taking cuttings or by breaking off tubers. As humans began to do this, planting vineyards, potato fields, olive groves, and orchards, they naturally took cuttings from the rare plants with bigger or tastier produce. As new, useful mutations or seedlings from spontaneous crosses between clones showed up in the orchards, these too were noticed and favored. Rare genes quickly stacked up, and soon the plants were very different than their wild ancestors.

People also learned how to gather seeds from stands of wild grasses and other small plants, both annual and perennial. Some harvested seeds were spilled or deliberately scattered around villages, and these would have been harvested first. The rules of the game had suddenly changed, and now the plants with the biggest, showiest, easiest to harvest, fastest-sprouting seeds became the winners. The more frequently this tournament between plants was held, the faster the "domestic genes" piled up.

The plants in the middle, the perennial herbs, could have been domesticated in either way. Like trees they can be propagated by cuttings or tubers. But their smaller size made this impractical for early farmers – imagine the thousands of cuttings required for just one small field. Like annuals, they can be established from seed – farmers do this every time they plant a field of alfalfa or clover. But alfalfa didn't need to evolve much to become a hay crop, while grains are much changed from their wild ancestors. Because they must build at least a few durable structures, perennial plants always take at least a little longer than annuals to reach maturity, so they can never play as many tournaments as annuals in a given number of years. And even when they do play, the higher genetic diversity within each perennial plant means that even the winners will bear mostly loser offspring. The annuals simply evolve – domesticate in this case – faster.

Once people had a few good (annual) grains and nuts and fruit tree species, they would have abandoned the low-yielding wild or partially domesticated perennial herbs.

A third domestication road is now possible. The tree and annual-grain paths were "natural" in the sense that the plants which produced the best seeds, fruits, or tubers in the field were also the ones people automatically saved for replanting. In the modern era, we have used artificial selection to greatly increase the yield of these crops. Artificially selected plants are often not the biggest or highest yielding individuals in the field. Sometimes plant breeders select the shortest individuals. Mixed with big plants, short plants have few seeds, something nature or pre-scientific farmers would never select. But once the lines breed true and all plants are short, the yield of the group is increased because less energy is spent battling for height advantage.

While natural domestication methods applied to perennial herbs would inevitably lead them to be either more annual or more treelike, artificial selection can maintain their overall form yet increase seed yield. As with artificial selection during the green revolution, yields may go down for a time before they go up.

But what about the herds of meat mice? While rodents may or may not have the genetic variation necessary for this kind of transformation, the idea is not as ridiculous as it sounds. Gentle, tuskless elephants or giant, slow, furry rats would not survive on the Serengeti, but add a shepherd to the equation to fend off predators, and you might get something similar to sheep and cattle. Millions of years of evolution never came up with docile, hornless sheep, and without shepherds, these animal forms would be impossible to maintain, even if they arose by chance. But nature did invent shepherds and, later, scientists. With artificial selection sheep could be selected to reproduce more like rabbits. Indeed some modern breeds of livestock do mature

PRAIRIE FESTIVAL RECORDINGS

September 25-27, 2009, The Land Institute

QUANTITY	TITLE	SPEAKER
________	Report from The Land Institute	Land Institute staff
________	When environment boils the political pot and ecology wins in the clash of world views	George M. Woodwell
________	Social and biological complexity	Verlyn Klinkenborg
________	Global warming: are we doomed?	Richard Harris
________	Endangered species, climate change and legislators: Odd but certain bedfellows	Mike Phillips
________	Economics and ecology: A new synthesis	John Todd
________	Resilience: A positive substitute for growth	Wes Jackson

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more quickly and produce larger litters than the old breeds, and many breeds now lack horns. In the case of domestication, the ancient past is not much of a guide to the present. New forms of animals and plants evolved in the age of the shepherds and farmers about 10,000 years ago. Other new kinds of plants and animals are now possible in the age of scientists. One of them is perennial grains.

Despite receiving no fertilizer, Miscanthus, a perennial, exceeded by half again corn's aboveground growth in corn country, Illinois. The Miscanthus pictured grows at The Land Institute for a cooperator to evaluate for biomass yield. In exchange, our grain sorghum candidates are being tested in Alabama. Scott Bontz photo.

YES, THEY CAN

DAVID VAN TASSEL

Skeptics question whether any perennial grain crop, investing energy below ground to survive winter, could equal annuals in the aboveground growth that can go to making seed for our food. A study in the journal Plant Physiology lays that suspicion to rest.

Corn is the most productive grain crop in many places around the world. In Iowa and Illinois it was thought to be unbeatable. But in Frank G. Dohleman and Stephen P. Long's large-scale, side-by-side study at the University of Illinois, a perennial grass genus from Asia, Miscanthus, produced some 30 tons of aboveground growth per hectare, compared with corn's 20 tons. And Miscanthus did so with no fertilizer, while the corn was fertilized at the recommended high rate. Miscanthus is paying its bills to survive the winter and despite – or because of – this, it still builds a massive stalk system.

Another of Long's papers suggests that Miscanthus produces slightly more leaf mass than corn, but well over twice the stalk mass. Stalks are an energetic "sink": though superficially green, they import much more of the sugars made by photosynthesis than they export. And this is the case for seeds, which do some photosynthesis early on, but largely act as sinks. Conceptually, sinks are easily interchangeable. To make that shift requires finding the necessary genetic variation and a lot of time. But plant breeders have repeatedly accomplished this, selecting for reallocation from stalks to seeds. It has been one of the main sources of increased seed yield in modern wheat and rice.

Though the Illinois study's plants happen to be sterile hybrids, there are many Miscanthus species that produce seeds. A biofuel breeding company is evaluating seed-propagated Miscanthus lines for biomass production potential. They do not believe that only asexual clones are capable of high yield.

Most of the so-called "second generation" biomass crop candidates – Miscan-thus, sugarcane, switchgrass, willow, poplar, bamboo – are perennials. Their biomass yield potential isn't always higher than with comparable annuals. But even when it isn't, the reduced energy inputs for perennials often make the net energy yields higher than for high-input annuals. In Illinois, Miscanthus produced 60 percent more harvestable energy than corn, with an estimated one-fourth of the energy input. Additional bonuses with perennials: greater soil conservation and carbon sequestration.

The case for the greater sustainability of perennial food crops rests on the same logic that rapidly led plant breeders to focus almost exclusively on perennial biofuel crops. Grain is a biofuel. Not only can it be burned in a power plant, or converted to ethanol – more easily than can leaves and stems – it can be "burned" in people and livestock. If it is expensive and unsustainable to use annual crops to produce vehicle fuel, it is equally expensive and unsustainable to use annual crops for human fuel.

TOO WEIRD

DANA WILDSMITH

Last June I was bitten by a rattlesnake
in my small town just north of Atlanta.
We're in a drought here in Georgia; our dry woods
heat up of an evening like an old farmhouse
which is why that snake was stretched out on the shaded road
to catch a breeze – but instead he caught me.

I must be making this up, people tell me,
because there are no rattlesnakes
in Georgia. I assure them there's at least one, despite Atlanta
doing its best to pave all the snakey woods
in north Georgia, to usurp every farmhouse
with a starter home, to bulldoze roads

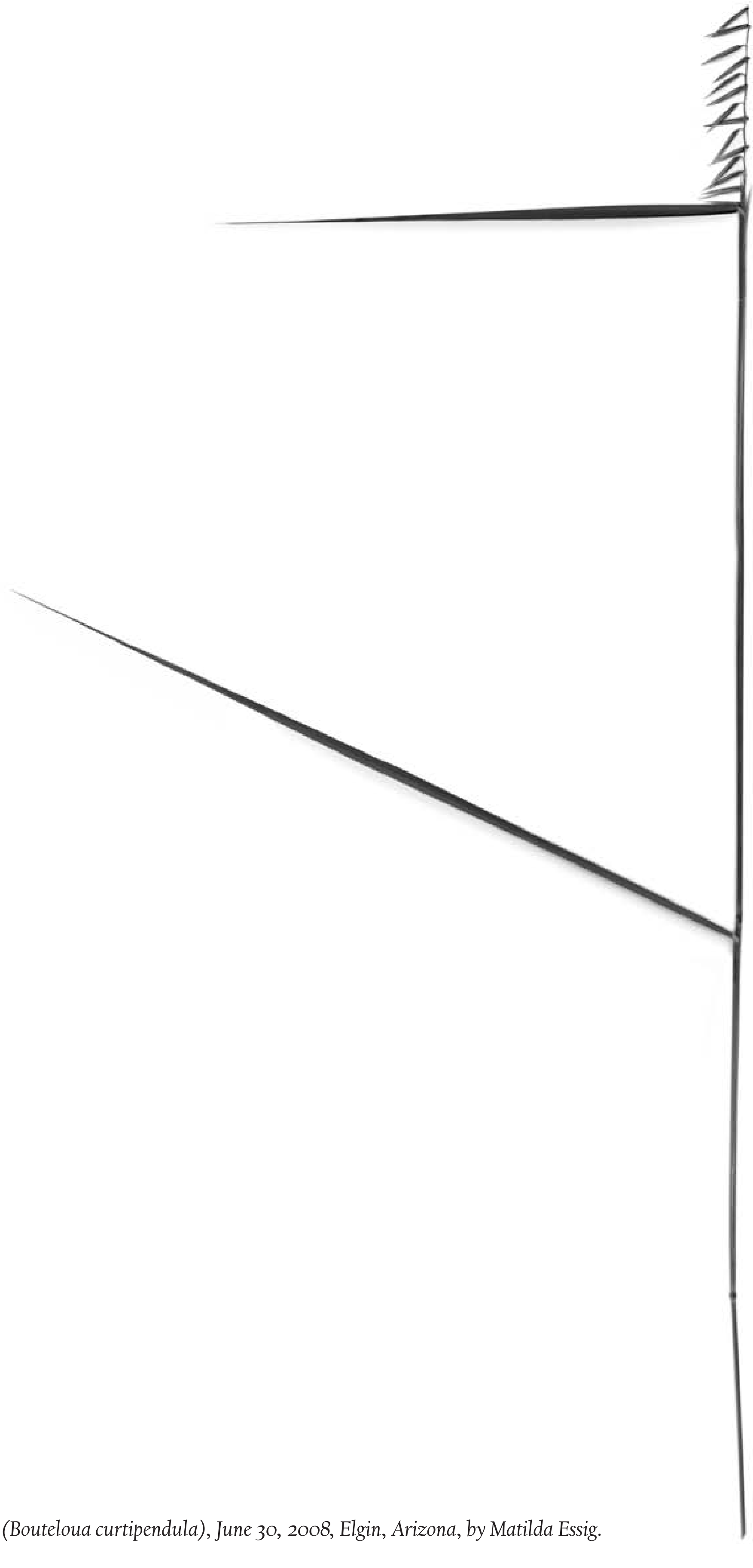
along every ridgeline. It's the power of the paved road:
no dirt roads, no snakes, right? It's me
people are a little afraid of now. Rattlesnakes
can be urbanized out, people around Atlanta
have come to believe, and they don't want me and my woods
and my road proving them wrong. So they tell me my old farmhouse

is too weird, that the way I live is too weird – in a farmhouse
with no air conditioning fronted by a dirt road
I fight the county to keep unpaved. They tell me
I should cut down my woods where rattlesnakes
can live, that I should wear boots and carry a gun. Atlanta
has sanitized into conservation zones all its woods

and so should I, and then I should stay out of those woods.
If I told them a snake lives in the attic of my farmhouse
and maybe in their attics, too, if I reminded them all roads
are just skin over earth where crawly things live – they'd blame me
even more than they do now for letting a rattlesnake
bite me. They say it's because I don't have a progressive Atlanta

mindset that I allowed bad nature to hurt me. Atlanta,
what makes you believe the woods
will stay where you've pushed them? My old farmhouse
used to perch on a logged plain of plowed fields split by the same road
now so shadowed by trees that their cooling shade drew me
out for a walk one evening last June, and there a rattlesnake

bit me. Simple as that. It wasn't the fault of the dirt road,
nor my fault for living in a farmhouse north of Atlanta where my woods –
same as your city neighborhoods – sometimes breed rattlesnakes.



Sideoats grama (Bouteloua curtipendula), June 30, 2008, Elgin, Arizona, by Matilda Essig.

PRAIRIE FESTIVAL

SEPTEMBER 24-26, SALINA, KANSAS

Celebrate and share your thoughts about land and country, at a place working to make farms like natural ecosystems – resilient, healthy, and healthful – with these speakers: biologist and "Living Downstream" author Sandra Steingraber, agrarian writer Wendell Berry, "A Conservationist Manifesto" author Scott Russell Sanders, ecological economist Joshua Farley, Seed Savers Exchange co-founder Kent Whealy, and Land Institute President Wes Jackson. Plus: a barn dance, images by Matilda Essig (see left), music by Ann Zimmerman, Saturday supper and, weather permitting, a bonfire. Free tent camping. Updates will appear under Calendar at landinstitute.org.

Saturday

Friends of the Land _____ x $12 = _____

Others _____ x $16 = _____

Sunday

Friends of the Land _____ x $6 = _____

Others _____ x $8 = _____

Student rate for weekend, without supper

_____ x $10 = _____

Attending □ Saturday □ Sunday

Children under 12, free _____ x $0 = _____

Supper Saturday, paid by September 17

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Vegetarian, not vegan, meal? □ Yes □ No

Enroll as Friend of the Land, one year, tax-deductible, $50 minimum. You are already a friend if you have given since September 30, 2009 $ _____

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Address _______________________________

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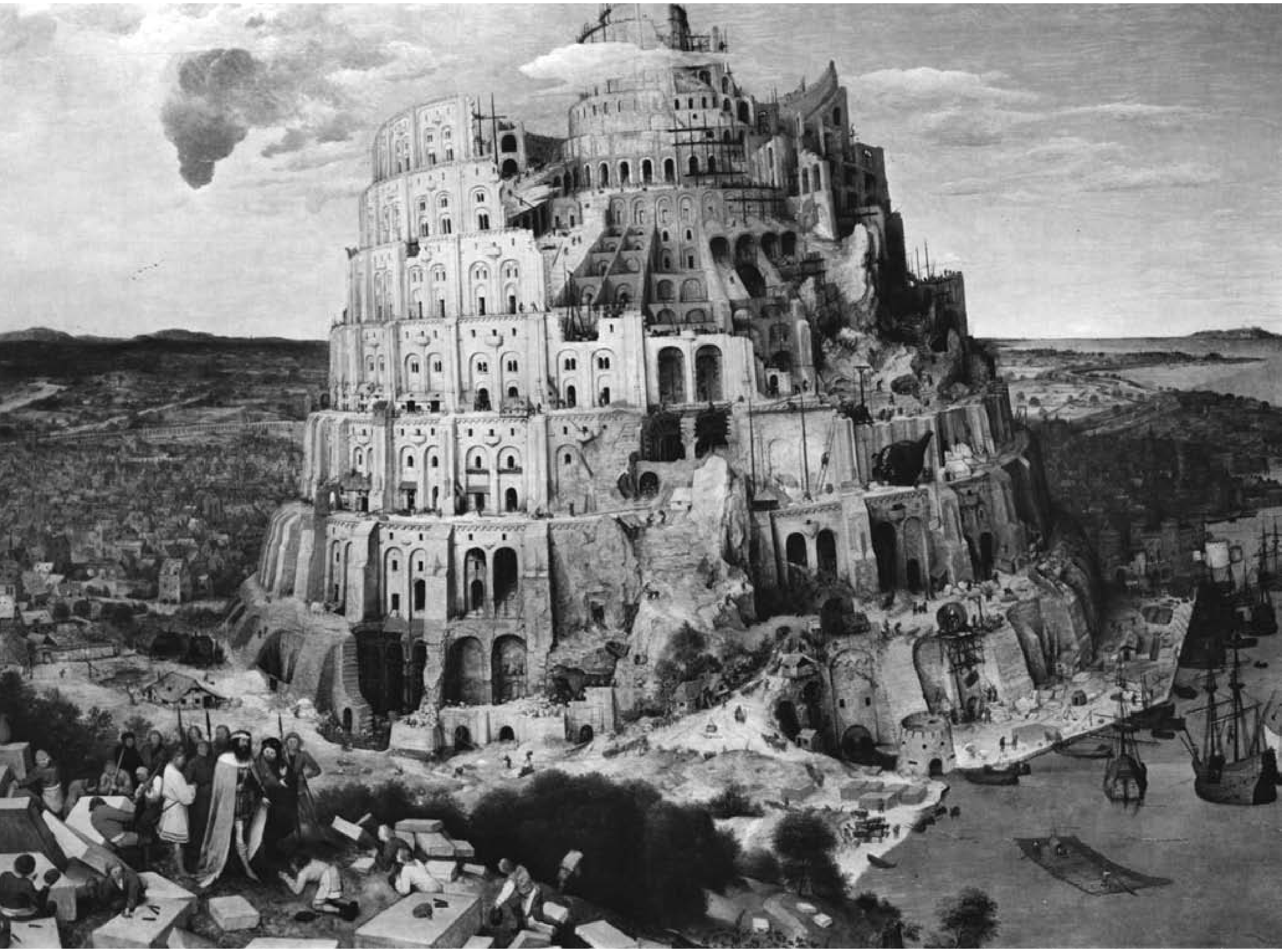

"The Tower of Babel," by Pieter Bruegel the Elder. Now proposed in response to agriculture's ills: the folly of sky-scraping greenhouses, which use costly electricity instead of what can be had for free from the sun.

WRONG ON SO MANY LEVELS

STAN COX AND DAVID VAN TASSEL

At last, the ecological, social, and nutritional disaster of American agriculture is grabbing popular attention, in books, films, conferences, and projects. The critiques are often right on the money. But many of the proposed solutions, including local eating, food cooperatives, home gardening, organic farming, and abolition of factory-style livestock raising, while worthy, cannot provide a permanent solution to degradation of our soil and water.

One of the most striking examples of ill fit between problem and proposed response can be found in the July/August issue of Smithsonian, and more thoroughly in the November 2009 issue of Scientific American, where Dickson Despommier, a professor of public health and environmental health sciences at Columbia University, makes the case for what he calls "vertical farming." After doing a very good job of describing the terrible toll that agriculture takes on soil, water, and biodiversity, Despommier lays out a proposal to replace soil-based farming with a system of producing food crops in tall urban buildings – that is, he writes, to

> grow crops indoors, under rigorously controlled conditions, in vertical farms. Plants grown in high-rise buildings erected on now vacant city lots and in large, multistory rooftop greenhouses could produce food year-round using significantly less water, producing little waste, with less risk of infectious diseases, and no need for fossil-fueled machinery or transport from distant rural farms.

Despommier describes how one of his scenarios, which are based on the use of hydroponic or "aeroponic" methods of growing plants without soil, might work: "[L]et us say that each floor of a vertical farm offers four growing seasons, double the plant density, and two layers per floor – a multiplying factor of 16 (4 x 2 x 2). A 30-story building covering one city block could therefore produce 2,400 acres of food (30 stories x 5 acres x 16) a year." By extrapolating numbers like those and assuming extraordinary leaps in technology, as well as the repeal of Murphy's Law, he has made such a convincing case for vertical farms that, he claims, "many developers, investors, mayors and city planners have become advocates."

The idea for vertical agriculture grows out of the realization that there are not enough exposed horizontal surfaces available in most urban areas to feed urban populations. But even if vertical farming were feasible on a large scale, it would solve no agricultural problems; rather, it would push the dependence of food production on industrial inputs to even greater heights. It would ensure such dependence by depriving crops not only of soil but also of the most plentiful and ecologically benign energy source of all: sunlight.

Agriculture as it has always been practiced – call it “horizontal farming” – casts an extremely broad, green “net” across the landscape to capture solar energy, which plants use in producing food. Photosynthesis converts a small percentage of the solar energy that falls on leaves into the chemical energy in food. But that small percentage is enough; sunlight is plentiful, and left to themselves plants do not have to rely on any other source of energy to grow and produce.

For obvious reasons, no one has ever proposed stacking solar photovoltaic panels one above the other. For the same reasons, plots of crops cannot be layered one above the other without providing a substitute for the sunlight that has been cut off. Even with all-glass walls, the amount of light reaching plants on all but the top story of a high-rise would fall far short of what is needed. On a sunny day, a room with plenty of windows may look well-lit to our eyes’ wide-open pupils, but that light intensity is a tiny fraction of what is needed for crop production. A significant portion of the light hitting the building would be turned back by the glass, and direct sunlight would penetrate into the interior of a vertical farm only when the sun is low in the sky – especially if, as Despommier recommends, two layers of plants are stuffed into each story. Even then, it would reach the crop plants at a low angle, so that each square inch of leaf would receive much less light than if the light were hitting the leaf from above. So the lion’s share of a vertical farm’s lighting would have to be supplied artificially, consuming resource-intensive electricity rather than free sunlight.

We decided to ask, “What would be the consequences of a vertical-farming effort large enough to allow us to remove from the landscape, say, the United States’ 53 million acres of wheat?” That’s not an unreasonable question. In fact, it follows from Despommier’s own reasons for promoting the practice. He argues, correctly, that soil is currently being abused on a massive scale; therefore, to address the problem, vertical farming would need to displace agriculture from a large proportion of the currently cropped landscape.

Our calculations, based on the efficiency of converting sunlight to plant matter, show that to equal current US wheat production with vertical farming would, just for lighting, require eight times as much electricity as our utilities generate in a year. And even if it were energetically possible, growing the national wheat crop under lights could substitute for only about 15 percent of US cropland. Could it succeed, that energy buildup of unprecedented scale would still leave 85 percent of cropland in place. (To see the calculations, go to losingourcool.com/vertical.)

Despommier suggests using renewable sources to supply the power needed for vertical farming, but fails to consider the scale-up this would take. Wind, solar, biomass, geothermal, and other renewable electricity sources combined account for about 2 percent of US generation. So to grow our wheat vertically using renewable sources would mean boosting that sector 400-fold just to run the lights. His proposals for doubling plant density, using round-the-clock light or pushing year-round production, even if they could be made to work, would increase production per unit of area, but would not decrease the energy needed for lighting per unit of food produced.

Maybe trying to satisfy the nation’s huge grain requirements with vertical farming is too ambitious. Assume instead that we were to take a more modest approach and grow all vegetables under lights. If they received a similar level of lighting per unit area to that used for wheat, we would "only" have to double our national electricity generation. But removing all vegetable production from the landscape would preserve no more than 2 percent of our currently cropped soils.

Based on its energy requirements for lighting alone, vertical farming would be incapable of substituting for a substantial share of our farming. But the lighting problem is only the first among many obstacles facing high-rise agriculture. Climate control to achieve suitable growing conditions would add huge energy requirements. And light fixtures would release more energy as heat than as light, which in summer would put huge loads on air conditioning. To maintain the good health of plants grown indoors, humidity and air circulation must be precisely controlled, often at a high energy cost. And before any of those needs would come the gargantuan resource requirements for construction of the towers themselves.

The solution to soil and water degradation is not to strip food-producing plants from the landscape only to grow them, deprived of sunlight, in vertical factory farms. Instead, we have to address the Achilles heel of agriculture itself: that it has displaced, on a massive scale, diverse stands of natural perennial vegetation, such as prairies, savannahs, and forests, with monocultures of ephemeral, weakly rooted, soil-damaging annual crops such as corn, soybean, and wheat. The weaknesses of the current food-production system have been compensated for with fossil fuels and other resources. But those increasing efforts have only worsened farming's ecological damage.

The landscape cannot be saved by greater resource use, as would occur with "vertical farming." It will be saved by what we might call "three-dimensional farming," a system that is arranged horizontally across the landscape to capture and use sunlight, but that also puts down, deep, long-lived roots to protect the soil, manage water and nutrients efficiently, and help restore the below-ground ecosystems that agriculture has destroyed. That will require converting cropland to the production of diverse perennial crops. It will mean a reliance on natural processes, not technological fantasies.

Neither philosophical liberalism championing liberty nor philosophical socialism championing equality will save us from ourselves. Human history will end in ecology, or nothing. – Stan Rowe, "Home Place"

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Slender grama (Bouteloua repens), August 16, 2008, Elgin, Arizona. By Matilda Essig.

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THE WRITERS AND ARTISTS

Matilda Essig, a painter by training, uses a digital scanner, computer, and inkjet printer to make highly detailed prints of native grasses in the Apache Highlands of southeast Arizona. Her home there is on five acres that she restored using rotational grazing with cattle. At the Prairie Festival she will show large color prints of the grasses she worked with in the restoration. Essig's work is in private and corporate collections, and at national parks and wildlife refuges in the Sonoran Desert. Her Web site is matildaessig.com.

Jim Richardson is a photographer for National Geographic. His Web site is jimrichardsonphotography.com.

David Van Tassel and Stan Cox are Land Institute plant breeders. Cox's new book is "Losing our Cool: Uncomfortable Truths About Our Air-Conditioned World (and Finding New Ways to Get Through the Summer)."

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