

CHAPTER 2

HOW WILL WE FEED OURSELVES?

FARMING TO FIT THE LAND: GROWING FOOD LIKE A PRAIRIE

The native peoples who inhabited these lands long before us worshipped the Earth; they were educated by it. They didn't require schools and churches—their whole world was one.

—MICHAEL ABLEMAN, organic farmer, Goleta, California

How do we act on the fact that we are more ignorant than knowledgeable? Embrace the arrangements that have shaken down in the long evolutionary process and try to mimic them, ever mindful that human cleverness must remain subordinate to nature's wisdom.

—WES JACKSON, director of The Land Institute

I was at a friend's family reunion in Pipestone, Minnesota, a farming community in the squared-off, smoothed-out-straight corner of the state. Neat rows of wheat marched up to the doors of the Kingdom Hall, veered around the Quonset hut and its covey of pickups, then folded back together and marched on for miles.

Inside, we had hardly touched the Jell-O salad when news of the approaching weather snaked its way up and down the long banquet hall. Heads turned toward the southern doors and long-legged men began stepping over the benches that lined the tables. They bent down to whisper in the ears of other men, who excused themselves and swung their legs over and out.

Through the doorframe, we could see a sky the color of carbon, a sky that would come off on your hands if you touched it.

I made my way out to the parking lot where men in their church clothes leaned against trucks dusted the same flat color as the soil. In silence they watched the weather come. A few lit cigarettes and winced as the clouds roiled, like smoke barreling before a runaway fire. “It’s hail,” said one of them finally. The others were already crushing butts and climbing into their Dodges and Chevys, peeling out to join the caravan. Wordlessly, the kids at my table collected silverware while their moms stacked plates and whisked tablecloths away. The festive air had turned funereal, and I had the feeling it wasn’t the first time.

That storm turned into one of the hardest hails to hit southwestern Minnesota in a decade. What I realized then, viscerally, I knew already. Farmers are responsible for protecting their crops from things they cannot control. Today’s farmer in southwestern Minnesota has a huge spread, and because the fields are planted in one species, one variety, and one growth stage, the losses, when they come, are catastrophic. Having put their eggs in one basket, they are at nature’s mercy, caught in the crosshairs of drought, floods, pests, hail, and eroding soils. If anyone knows about being booted from the Garden of Eden, it’s farmers.

What’s amazing to observe is a natural grassland—a prairie—under the same kind of assault. Some of the grasses suffer, but most survive quite well, thanks to a perennial root system that ensures next year’s resurrection. There’s a hardiness about the plants in a wild setting. When you look at a prairie, you don’t see complete losses from anything—you don’t see net soil erosion or devastating pest epidemics. You don’t see the need for fertilizers or pesticides. You see a system that runs on sun and rain, year after year, with no one to cultivate the soil or plant the seeds. It drinks in no excess inputs and excretes no damaging wastes. It recycles all its nutrients, it conserves water, it produces abundantly, and because it’s chockfull of genetic information and local know-how, it adapts.

What if we were to remake agriculture using crops that had that same kind of self-sufficiency, that ability to live amiably with their fieldmates, stay in sync with their surroundings, build soil beneath them, and handle pests with aplomb? What would agriculture look like?

Well, that depends on where you live. Wes Jackson thinks it would look like a prairie. Jack Ewel thinks it would look like a tropical forest. Gary

Paul Nabhan thinks it would look like a floodwashed desert. J. Russell Smith, were he alive today, would vote for a New England hardwood forest. The common theme is that the agriculture in an area would take its cue from the vegetation that grew there before settlement. Using human foods planted in the patterns of natural plant communities, agriculture would imitate as closely as possible the structure and function of a mature natural ecosystem. Threading our needle with the roots of such a stable system, we would sew up one of the deepest wounds on the planet—the gash made by till agriculture.

In many ways, this “farming in nature’s image” movement is the most radical in this book, and perhaps the most important. As any economist would tell you, you can’t eat widgets. Food is what is called a complementary; it’s a given need that will always be with us, and despite what science fiction says about pill meals, there is no substitute.

Years after the hailstorm, I am once again in farm country, this time in Kansas, on my way to the country’s premier enclave of agricultural researchers seeking to mimic nature’s patterns. As I drive, a crew cut of wheat fields surrounds the car in all directions, as far as the eye can see. From the air it must look cut from a tool and die machine—straight rows of alternating green and brown, edged with an angularity foreign to living things. The soil beneath the stalks is plainly visible, all hint of weediness rounded up by chemical sprays. Nothing extraneous is allowed to grow here; everything has been stripped down to its least diverse form.

Whatever is left of the biotic community is harnessed and tuned to the production of one star: the cash crop. The fields have a factory-floor efficiency about them, and every now and then I see the floor managers, two stories up in Big Bud, Model 747 tractors, checking their six television monitors to see what’s happening on the ground. Plumes of diesel smoke and soil billow behind their rigs, like live volcanoes spewing.

The soil plumes bring me back to a conversation I had at the Ravalli County Fair with a stoop-backed rancher who had farmed in Kansas during the Dust Bowl. He described windrows of soil so high that the cows used them like ramps to walk over the fences and out. “It was on account of plowing where we had no business plowing,” he told me, “and what got lost on that wind, we never got back.”

When I get lost in my wanderings around the wilderness areas of Montana, I usually don't realize it for a while. When I do, I have to rein in a skittery panic and try to think of how I got there, which landmarks I remember. Only then can I find the trail home. In agriculture, after being lost for the longest time, it's time to sit down and think.

HOW WE WOUND UP IN THE BOX CANYON OF INDUSTRIAL FARMING

It was ten thousand years ago that we split open the rich, ripe-smelling soil for the very first time. We saved a seed, planted it, and rejoiced when it grew up, spilling its harvest right into our hands. We celebrated our release from the gamble of hunting and gathering, and brought bumper crops of grain and babies into the world. The more babies we produced, the more land we had to put under production to feed our brood. We began to work the land harder and harder, moving up slopes and into other places we had "no business" farming. Although we improved our odds of a dependable larder, we had unwittingly stepped onto what plant breeder Wes Jackson calls a "treadmill of vigilance." The more we tamed and sheltered our crops, the more they depended on us for their survival.

By now, our crops are so far from the adaptivechutzpah of their wild ancestors that they can't do without us and our petrochemical transfusions of fertilizer and pesticides. In our quest for ever-increasing production, we removed their inborn defenses. We isolated them from mixed species groupings, narrowed their genetic diversity, and gutted the health of their soil.

Of these three, say historians of agriculture, eviscerating soil was our greatest misstep. Topsoil is essentially nonrenewable. Once eroded or poisoned, it can take thousands of years to rejuvenate itself. Rather than opt for a self-sufficient, perennial plant community that would batten down this black gold, we opted for the rip-roaring growth of annuals, which requires us to disturb the soil each year.

Each time we plow, we simplify the soil, taking away some of its capacity to grow crops. We break apart its intricate architecture and wreak havoc with the dream team of microfauna and microflora that glues it together into colloids, or clumps, of soil and organic matter. This clumping is vital; it leaves air channels like veins throughout the soil, giving water a way to sink

down deep. Soils that are plowed too fine or packed too hard lose their colloids, and with them the art of retaining water. Parched air sucks the ground dry, and when the winds blow, talcum-powder topsoil coats the hoods of cars in town.

When rain strikes the hard pack, it can't shimmy down to the miles of thirsty roots as it should. Instead it glances off and runs in sheets, rills, and rivulets, murky and bloodstained, to the sea. The blood is soil, the living plasma of the Earth, sloughed off at a rate of five to one hundred tons per acre per year—a massive heist. Some Palouse Prairie wheat fields in Washington, on the shameful side of that equation, have the potential to lose one inch of topsoil every 1.6 years. In Iowa, up to six bushels of soil are washed out to sea for every bushel of corn produced.

What's left behind is a little deader as well as a little thinner. Behind the rest stop on Highway 7, I trespass a ways into a Kansas wheat field and bring up a handful of the bladed, pulverized, chemically amended soil. It's not chocolate-pudding black like the soil under the first plowed prairies must have been. It's beige and it doesn't smell as dank or fecund as it should—it doesn't smell like death and life commingled. The fungi that once wrapped their threads around rootlets to extend their reach, the brotherhoods of beneficial soil organisms, the bacteria that spun airborne nitrogen into food—they're all down to a skeleton crew, a shadow of their former selves. With the links among them severed, there is less "bootstrapping," less of the power that comes from several species working in biotic conspiracy to lift up the whole community.

The wildly fertile "postage stamp" prairies still scattered throughout the Great Plains give fragmentary testament to what we once had. In his eloquent book *The Grassland*, Richard Manning describes these vestiges as "pedestals carved by the plow." From the crown of some of these pedestals, once level with the land, you now have to drop down three feet to reach plowed soil. Such is what we have lost.

In other places, the scalp of the Earth is so thin that our plows are already mixing it with subsoil, which doesn't have the organic history that topsoil has. The grand larceny of harvest removes even more organic matter from these fields. Even in places where the stubble is plowed back in before planting, the nutrients are often wasted, pried away by hard rains before any plants are even visible. Over the years, these heists and the mistimed feedings add up to decreased fertility, a slow sterilization of our nation's real

goose with the golden eggs. “Over a mere century of tilling the prairie soils of North America,” says ecologist Jon Piper in his book *Farming in Nature’s Image*, “we have lost one third of their topsoil, and up to 50 percent of their original fertility.”

Part of our loss can be traced to our fetish for production, our eagerness to turn an organic, nature-based endeavor into a factory: the farm as machine. Author and Kentucky farmer Wendell Berry says Europeans came to this continent with vision but not with sight—we couldn’t see the value of what was right before us. We set to work removing the land’s native dress and imposing a pattern of our own making. Exotic plants instead of indigenous ones, annuals instead of perennials, monocultures instead of polycultures. This disruption of a natural pattern, says Wes Jackson, is the definition of hubris.

Rather than looking to the land and its native peoples for instructions (what grows here naturally and why?), we issued arbitrary orders, expecting our farmland to fulfill many agendas, some of which had nothing to do with feeding people. Wheat, for instance, was leveraged to help us win the First World War. The European continent was overoccupied with fighting, and in many places, crops were neither planted nor harvested. To fill that void, we boarded battalions of newly motorized tractors and plowed our home soil right up to the Rockies, uprooting massive amounts of virgin prairie in what would later be called the Great Plow-up.

This was the finale of a movement that had begun with the first sodbusters and their steel-laminated moldboard plows, the only tools strong enough to break the tangle of prairie roots, some as stout as a homesteader’s arm. It was considered backbreaking but heroic work, at least by white settlers. A Sioux Indian watching a sodbuster turn prairie roots skyward was reported to have shaken his head and said, “Wrong side up.” Mistaking wisdom for backwardness, the settlers laughed as they retold the story, ignoring the warning shots that fired with each popping root.

Having broken the prairie, we were ripe for the 1930s disaster of deep drought and relentless winds called the Dust Bowl. It got so bad our topsoil started showing up on the decks of ships a hundred miles off the Atlantic coast. One day in 1935, as officials in Washington, D.C., were hemming and hawing about what to do, a cloud of Great Plains soil fortuitously blew into town. A frightened Congress coughed, teared, and eventually created the Soil Conservation Service (SCS), an agency that would cajole and even pay

farmers to conserve their soil. SCS agents were evangelical, and farmers were ready to repent, and together they were successful in getting our most erodible lands replanted to perennial, soil-holding grasses.

The institutional memory proved short, however, and when another world war had come and gone, we looked around and wondered why we weren't "using" every inch of the breadbasket. Earl Butz, the secretary of agriculture under Richard Nixon, reflected the nation's hubris by admonishing farmers to plow "fencerow to fencerow." Forgetting the lessons of the Dust Bowl, farmers filled in draws and bulldozed windbreaks, spending millions of federal dollars to obliterate what the SCS had spent millions of dollars planting.

We now had acres of new canvas on which to paint the next face of industrialized farming: the Green Revolution. In what was heralded as the answer to world starvation, breeders unveiled new hybrid strains of crops that promised phenomenal yields. Because of their hybrid nature, however, these new plants couldn't pass their genetic traits on to the next generation. So farmers around the world abandoned the time-honored (and ecologically prudent) tradition of seed saving and added a new expense to their ledgers: purchasing hybrid seeds.

The homogenization of fields spread rapidly. Varieties of crops that had once been used because they did well on a south-facing slope or were able to prosper in the Banana Belt or the Little Arctic regions of a state were forgotten. In places like India, where there were once thirty thousand land-tailored varieties of rice, their replacement by one super variety swept away botanical knowledge and centuries of breeding in one fell swoop.

Too late, farmers realized that touted yields were only promised, not guaranteed. In your part of the world, the fine print read, you may have to do a little goosing to get advertised yields—more water, more thorough tilling, more pest protection, more artificial fertilizer. But once the farmer next door had taken the bait and started to grow high-yielding varieties, you had to as well, so as not to be left behind. Together, like a slow pour over a large falls, we switched to a system of farming that mimicked industry, not nature.

Chasing economies of scale, experts advised farmers to get big or get out. Mechanization allowed them to "service" larger fields with less labor, but it meant steep capital investments: more land, bigger equipment, enormous debt. For the small operator, there was suddenly no room to dance in the margin, or to take care of your land the way you'd like. When you are in debt

for a \$100,000 combine, you can't afford to switch to alfalfa one year to rest the land. To hold the debt at bay, and to qualify for government subsidies, you have to farm volume.

We quickly went from growing food to sustain ourselves to growing so much food it became a surplus—an export item and a political tool. The farm became just another factory producing another product that would keep the United States in the global catbird seat. The internal controllers, those farmers with their ears to the land, determined to pass on good fertile soil to their progeny, gave way to remote-distance controllers—agribusiness and public policy.

To serve these “distance princes,” as *Grassland* author Richard Manning puts it, industrial farmers abandoned traditional ways of managing their lands, such as rotating crops, liming and fertilizing with animal manure, or producing a diversity of products in case one crop failed. Instead, they “focused” their farms—selling off their livestock and switching to one species grown in continuous cropping, which is, in effect, continuous robbing. They propped up flagging soil fertility with artificial nitrogen fertilizer produced with natural gas. Weed competition was quelled with herbicides, another petroleum product, while oil-based chemicals were used as a prophylactic against pest outbreaks (which by now were extreme, thanks to acres of identical plants with identical vulnerabilities). Suddenly, for the first time in ten thousand years of agriculture, farmers were beholden to the protection ring of petroleum and chemical companies, and were said to be growing their crops not so much in soil as in oil.

Once on that treadmill, the feedback loops began. Weeds and pests are wily by nature, and even if you spray them one year, not all of them will die. Those that manage to hack an immunity explode the next year, requiring even heavier doses of biocides. In the escalating war of “crops and robbers,” the more you spray, the more you have to spray.

Who's winning? Since 1945, pesticide use has risen 3,300 percent, but overall crop loss to pests has not gone down. In fact, despite our pounding the United States with 2.2 billion pounds of pesticides annually, crop losses have *increased* 20 percent. In the meantime, more than five hundred pests have developed resistance to our most powerful chemicals. On top of that bad news, the last thing we want to hear is that our soils are also becoming less productive. Our answer has been to rocket-boost fertility with 20

million tons of anhydrous ammonium fertilizer a year—as many as 160 pounds per person in this country alone.

Recently, the protection racket has jumped to a whole new level of menace. Tune in to TV in an agricultural state, and you'll see a slick commercial for a crop seed that comes pretreated with a herbicide that kills weeds but doesn't harm the growing seedling. Because the plant has been specially bred to grow unscathed by that brand of herbicide and none other, the company is assured future sales. There's something unsavory about this. A dependence forms, and product loyalty is instilled with no question about the wisdom of using that product. Evidently, this latest move has been in the offing for quite some time. According to a December 1982 *Mother Jones* article by Mark Schapiro, at least sixty U.S. seed companies were sold between 1972 and 1982, all of them to chemical and petroleum companies. At last count, sixty-eight companies have plans to introduce their own seed/herbicide combos. Good news, they say: Now that farmers don't have to worry about seedlings suffering from year-to-year herbicide carryover (which used to limit herbicide use), they can use as much as they want.

This is the kind of news that should worry all of us. At last count, leaching pesticide residues made agriculture the number-one polluting industry in this country. At stake is groundwater, which supplies half the U.S. population with its drinking supply, and which is nearly impossible to clean once contaminated. Farm families already know about contamination. Recent studies have shown that people living in rural parts of Iowa, Nebraska, and Illinois are likely to have pesticide residues in their wells, and to have higher than normal risks of developing leukemia, lymphoma, and other cancers. Nitrate levels (from fertilizer) in the drinking water of many farm communities also exceed federal standards, which may be why miscarriage rates in farm families are unusually high.

Nitrates are not the only thing draining from farmland. Money is, too. In 1900, if you put a dollar's worth of material and energy inputs into your farm, you'd produce \$4.00 worth of crops, an input-to-production ratio of 1:4. Today, even though we produce more food, our genetically pauperized, oil-hungry crops cost more to grow. It takes \$2.70 worth of oil-based inputs to produce \$4.00 worth of crops, an input-to-production ratio of only 1:1.5.

Moreover, because of the crops and robbers feedback effect, we will continue to need more and more inputs. Already, Cornell University ecologist David Pimentel reckons that society spends ten kilocalories of hydrocarbons

to produce one kilocalorie of food. That means each of us eats the equivalent of thirteen barrels of oil a year. Author Richard Manning cuts through these statistics to ask the important question: When you have a system that is one part farmer and nine parts oil, who do you think will have the ultimate power? Not small farmers, and certainly not the landscape.

According to data collected by Iowa State University in 1993, most farm families now rely on off-farm revenues for one half of their income. Those who don't make it wind up selling to those with ready cash—corporations, syndicates, investors. This spiral leads to fewer family farms and a brain drain from the rural countryside, a tragedy that Wes Jackson calls “fewer eyes per acre.” Already, 85 percent of our food and fiber comes from 15 percent of our farms. These megafarms are hardly what Thomas Jefferson envisioned when he saw a nation of yeoman farmers tending their 160 acres, beholden to no one.

What's most dangerous about this dependency—the crops on us and us on petroleum—is that it keeps us too busy to think what the real problems might be. Fertilizer, for instance, masks the real problem of soil erosion caused by a till agriculture of annuals. Pesticides mask a second real problem: the inherent brittleness of genetically identical monocultures. Money borrowed to pay for the fossil-fuel inputs masks a third real problem: the fact that industrial agriculture not only destroys the soil and water, it strangles rural communities. Though we don't want to admit it, our farms have become factories owned by absentee interests. With our help, they are liquidating the ecological capital that took the prairie five thousand years to accumulate. Every day, our soil, our crops, and our people grow a little more vulnerable.

What I want to know is, how long can our denial hold?

Before I get too deep into despair, I remind myself that I am headed to meet the one group of researchers who have stepped from denial's shadow and made it their business to expose the crumbling foundations of this system. The people at The Land Institute—fifteen staff members, nine interns, and three staff volunteers—are committed to devising an agriculture that is, in Director Wes Jackson's words, “more resilient to human folly.” On one of my driving breaks, I reread The Land Institute's literature, and its quiet, determined tone assures me as much as it amazes me. At core these researchers are farmers, and they think there is nothing more sacred than the pact between humans and the land that gives them their food. But they are

also realists, and it's made them revolutionaries. They're not afraid to acknowledge that it's not just a few problems *in* agriculture that need overhauling. It's the problem *of* agriculture itself.

The problem of agriculture is an old and pervasive one, explains Wes Jackson in a series of books including *New Roots for Agriculture*, *Altars of Unhewn Stone*, and *Meeting the Expectations of the Land*. It comes from an insistence on decoupling ourselves from nature, from replacing natural systems with totally alien systems, and from waging war on, rather than allying ourselves with, natural processes. The result has been a steady loss of ecological capital—the erosion and salting of soil, the steady domesticating and weakening of our crops. To find our way back, says Jackson, we have to remember what the ancestors of “our” crops were like in their own element.

Once wild creatures, our agricultural charges were shaped by an ecological context that bears little resemblance to our farming. Their natural ecosystems ran on sunlight, sponsored their own fertility, fought their own pest battles, and held down, even *built*, soil. But long ago, plants were removed from the original relationships they had with their ecosystems and pressed into our service. Now, writes Jackson, “Our interdependency has become so complete that, if proprietorship is the subject, we must acknowledge that in some respects they own us.” To break this codependent cycle, we have to stop fighting our crops’ battles and instead raise hardy crops in a farming system that brings out their natural strengths.

THE PARABLE OF THE PRAIRIE

“Essentially, we have to farm the way nature farms.” Wes Jackson, sixty-year-old fourth-generation Kansas farmer and modern-day Cain-raiser, arrived at that simple conclusion years ago, before he had the language to speak of it. It was his sixteenth summer and he was away from his family’s Kansas farm, roping and riding on his cousin’s cattle ranch in South Dakota. He was amazed that no one planted or tended it, yet the grass came up year after year, drought or no drought, through snow and blistering sun. There were rattle-snakes coiled right in the middle of it, and burrowing owls standing sentry outside their holes. “There was a rightness to it all,” he says now.

Another good rain fell while Jackson was working toward his Ph.D. in genetics at North Carolina State. His adviser, Ben Smith, popped his head in the door one evening and declared: “We need wilderness as a standard against which to judge our agricultural practices.” With this, the seed coat split, and a slow root began to burrow.

When Jackson was thirty-seven, on the fast track to tenure after writing a successful text called *Man and the Environment*, he got uneasy. Though he had an enviable post as creator of the Environmental Studies Department at California State University in Sacramento, he felt he wasn’t where he was meant to be. To the astonishment of his colleagues, he and his wife, Dana, packed up their three kids and returned home to Kansas. They moved into a partially earth-sheltered house that they had built along the Smoky Hill River, and in 1976, they began a school that focused on sustainable living practices. That school would become The Land Institute, a nonprofit research organization devoted to “an agriculture that will save soil from being lost or poisoned while promoting a community of life at once prosperous and enduring.” This new agriculture would take wilderness as its model, nature as its measure.

In Kansas, the wilderness was tallgrass prairie, the natural expression of the underlying layers of soil, the carnival of weather, the licking of fire, and the grazing of elk and bison. Prairie is what Kansas land wants to be, but for the most part, is no more.

I am startled, then, by what I see when I turn down Water Well Road to The Land Institute. With no warning, the bristle of wheat fields yields to a softer ensemble of wild-haired plants, stems akimbo, saturated with color and raucous with flowers and tasseled stalks. As I watch, wind enters like a dancer onto a crowded floor, parting the crowd, causing a bobbing and dodging of plants in its wake. The whole thing sways crazily for a moment, then settles in a perfect hush, like a band ending a jam by feel.

A sign by the road says that this is The Wauhob, a prairie miraculously spared a sodbusting, probably because it was up gradient, and hard to get plows to. My car literally rolls to a stop as I gawk, so welcome is this sight after the acre upon acre of ramrod efficiency I’ve driven through. From where I am now, I can see both wheat field and prairie, and it’s like a visual parable—Jacob and Esau, cut from the same cloth but of very different character. One is the expression of imposed will, the other the expression of

the land's will. An understanding intern spots me and interrupts his organic gardening chores to give me directions to the office.

The Land Institute headquarters is a modern brick house that was once home to an older couple. The bedrooms are now offices, and there's a kitchen and fireplace in the meeting room, where a dozen local women are stuffing envelopes and drinking coffee when I arrive. In "The Land's" twenty years of existence, its original 28 acres have grown to 270, an amazing accretion considering that this nonprofit operates solely on private funding and has never gone into debt.

Ecologist Jon Piper greets me in the foyer and asks about my drive, all the while migrating toward the door, as eager as I am to get out into the prairie. Piper is in his late thirties, bespectacled and bearded, with a quiet forbearance for visitors like me. He knows that what I experience here, my dip in the prairie sea, will be as important as what we say to one another. "We'll make a conceptual loop," he tells me. "Starting where all our thinking starts."

As we wade into the knee-high Wauhob, Piper comes to life, unconsciously bending and turning the heads of the plants as he talks, like a teacher touching the heads of students as they work. Though never planted by human hands, the prairie is choked with blossoms, grasses gently pouring over, seeds setting, new shoots growing, runners crisscrossing the earth in a web of decay, growth, and new life. There is no hint of hail damage or drought wilt, no such thing as weeds. Every plant—231 species in this patch alone—has a role and cooperates with linked arms with the plants nearby. I see diversity of form—grasses splaying upward to different heights and widths, a sunflower's bold expanse, a legume's dark leaflets, fernlike in their repetition.

Piper talks about the plants as if they are neighbors in a community—the nitrogen fixers, the deep-rooted ones that dig for water, the shallow-rooted ones that make the most of a gentle rain, the ones that grow quickly in the spring to shade out weeds, the ones that resist pests or harbor heroes such as beneficial insects. He also points out the butterflies and bees, the pollinators with wagging tongues, spreading rumors from one plant to another.

Beneath this unruly mob lies 70 percent of the living weight of the prairie—a thick weave of roots, rootlets, and runners that captures water and pumps nutrients up from the depths. A single big bluestem will have twenty-five miles of this fibrous plumbing, eight miles of which will die and be reborn

each year. These root remains, together with the leaves shed from above, will fall into the welcoming jaws of a miniature zoo—ants, springtails, centipedes, sowbugs, worms, bacteria, and molds. There are thousands of species in a single teaspoon, all tunneling, eating, and excreting, conditioning the soil crumb by crumb. Through their magic, dissolved nutrients are released to thirsty roots or stored in humus—the tilth that transforms the prairie into a living sponge.

The character of this belowground world is an expression of the bedrock, organic matter, rainfall, temperature, light conditions, and most important, the plant and animal community above. Pluck or plant something new and you change the microecology slightly. Plow, spray, and harvest every year, and you change it plenty. Some of the organisms you lose might be those that sponsor fertility, or help stave off insect and disease attacks, or produce hormones that tell a flower to unfurl or a root to push its snout deeper into the soil. It takes years to tune such an orchestra of microhelpers, but just moments to silence it.

The secret of the prairie is its ability to maintain both above-ground and belowground assemblies in a dynamic steady state. It's not the fact that nothing changes on the prairie (patches are always pulsing with change), but that the changes are never catastrophic. A prairie keeps pest populations in check, rebounds gracefully from disturbance, and resists becoming what it is not—a forest or a weed garden.

“Our goal at The Land Institute is to design a domestic plant community that behaves like a prairie, but that is predictable enough in terms of seed yield to be feasible for agriculture,” says Piper. To illustrate, he heads downslope from The Wauhob to stand in the zone between the prairie and wheat field I saw earlier. “Down there is our current agricultural ideal; we know it isn't sustainable, mainly because it loses soil and requires nonrenewable inputs. Up where you are, we have a sustainable ideal, but it won't feed us. Conceptually, we'd like to be somewhere in here, between the controlled rigidity of the wheat field and the wildness of the prairie.”

It's a concept that I'd read about in chaos and complexity literature. There exists a sweet spot between chaos and order, gas and crystal, wild and tame. In that spot lies the powerfully creative force of self-organization, which complexity researcher Stuart Kauffman calls “order for free.” Tropical agroecologist Jack Ewel also alludes to this free ordering when he

says, “Imitate the vegetative structure of an ecosystem, and you will be granted function.”

As the first step toward an agriculture that organizes itself into arrangements of strength, Piper’s job was to ascertain just what it was about the prairie’s structure that made it so tough. Is there a rule of thumb about which categories of plants consistently show up on a prairie roster, and what ratios they are in? Does it matter where they grow in relation to one another? In search of answers, Piper read everything he could about prairie ecology, and then spent seven glorious summers up to his eyebrows in wild pastures. He and his interns actually took scissors and clipped and bagged all the vegetation in certain plots. They identified each and every plant, separated them out into piles, and then dried and weighed them to find out what grew there. Through wet years and dry years, in rich soil and poor, Piper found that prairies do have a pattern that repeats itself, an order in the seeming chaos.

“The first thing that strikes us,” says Piper, “is that ninety-nine point nine percent of the plants are perennials. They cover the ground throughout the year, holding the soil against wind and breaking the force of raindrops. Hard rain hits this canopy of plants and it either runs gently down the stems or it turns into a mist. By contrast, when rain hits row crops, it strikes exposed soil, packs it, then runs off, taking precious topsoil with it.” Researchers have actually measured the difference; in identical downpours, they found that you get eight times as much runoff from a wheat field as from a prairie.

“Prairies just soak up a big rain,” says Piper. “I can come out here hours later, and The Wauhob still squishes when I walk on it.”

Besides being great sponges, perennials are also self-fertilizing and self-weeding. Thirty percent of their roots die and decay each year, adding organic matter to the soil. The remaining two thirds of the roots overwinter, allowing perennials to pop open their umbrella of vegetation first thing in the spring, long before weeds can struggle up from seed. As we walk through a particularly dense patch of prairie, Piper crows, “See? You wouldn’t have a chance in there if you were a weed.

“The second thing that strikes us about the prairie is its diversity,” Piper says. “We have two hundred and thirty-odd species right here on this knob—not just one species of warm-season grass, but forty species. Not just one nitrogen-fixing legume, but twenty or thirty. That means that there will always be some species or some variety of a species that can do well in our highly

variable Great Plains climate. I've been out here in dry years when the grasses barely reach your knee and there's yucca everywhere. Other years, after plenty of rain, you and I could stand three feet apart and not be able to see each other through the big bluestem. The species composition remains the same, but different species excel in different years."

Diversity is also the cheapest and best form of pest control. "Many pests tend to specialize on one host plant species, so when there's a diverse mix, pests have a harder time finding their target plant. Even if they manage to touch down somewhere in the field, the attack troops don't get very far. Disease spores may blow onto the wrong plant, or insect young may crawl into the wrong bud. With a diverse offering, attacks die down before they become epidemics."

The third signature of the prairie is its four classic plant types: warm-season grasses, cool-season grasses, legumes, and composites. Cool-season grasses come up early, set seed, and then bow out of the way, allowing warm-season grasses such as big bluestem to rule the rest of the season. Legumes such as cat's-claw, sensitive brier, and leadplant fix their own nitrogen, fertilizing the prairie with their bodies. Composites, such as goldenrod, asters, and compass plants, can flower anytime throughout the season. Although these four "suits" may vary in proportion from place to place, Piper found them in every prairie he waded through.

"Learning the secrets of the prairie gave us a goal to shoot for as we sifted through the countless combinations of plants that would qualify as prairie mimics in our agriculture. We knew we needed perennial grains grown in a polyculture, with the four suits of the prairie represented. The only question was how *many* different species in each group will we have to plant? Since it's impractical to have an agriculture with two hundred species, how much diversity will we need to get functional stability? Our intuition told us that we would probably have to plant many more species than we need and let the assemblage shake down over a few years to the handful that would provide human food. Just about then, 'community assembly' studies started to show up in the literature, and they suggested that you could get persistent communities containing as few as eight species. That was encouraging to us."

Breeding eight perennial crop species from scratch looks more feasible than breeding two hundred, but it's still a daunting challenge. Today, most of the food eaten around the world comes from only about twenty species, and

none of them are perennials! Some began as perennials, but over the ten-thousand-year odyssey of plant breeding, we systematically removed their hardy perennial traits, marching right by the sweet spot between wild and tame, and domesticating them until they were annual by nature.

A story is told about the moment Wes Jackson realized the full extent of this unhappy extreme in agriculture. Shortly after starting his school, Jackson took his students on a field trip to the eight-thousand-acre Konza Prairie near Manhattan, Kansas. One of them asked the innocent question, “Are there any perennial grains?,” and it made Jackson think. When he got back, he drew up a list of all the crops he could think of, separating them into either annual or perennial, herbaceous or woody, vegetative or seed/fruit yielding. To his surprise, there were crops that fit into almost all the categories, but there was a glaring blank in the space for HERBACEOUS, SEED-YIELDING PERENNIAL. It was a revelation in black-and-white.

PERENNIAL OPTIMISTS

Jackson and his staff started tearing apart the literature—surely someone must have done some plant breeding on perennial grains. They were disturbed to find that no one, save some folks looking at animal forage, had studied seed-yielding perennial grasses or legumes or composites. The reason?

“It was a nonstarter for career-oriented scientists,” says Jackson. “The common wisdom was that perennials, which spend most of their energy belowground, could never be made to produce copious seeds [the part that humans eat]. If they were to yield more seeds, the thinking went, there would be a trade-off belowground, and they’d lose their ability to overwinter.”

Jackson, who’d made a career of bucking conventional thought, said not so fast. The first question The Land Institute assigned itself was the one everyone else had skipped:

Can a perennial produce as much seed as an annual crop?

After two more years of library safaris and actual planting experience, The Land Institute staff was convinced that perennials *could* be bred to yield plentiful seeds without losing their perennial traits. Illinois bundleflower and wild senna, for example, were two wild perennials that, with absolutely no breeding, already approached the benchmark yield (the floor range) for wheat in Kansas: eight hundred pounds per acre. Considering that the wild

relatives of some of our crops have undergone four-, five-, even twentyfold seed-yield increases at the hands of talented breeders, the chances of upping yields for these new crops were good.

The trick this time around would be to increase seed yield *without* stripping the plant of its wild hardiness. Curious to see what artificially increased seed yield would do to plant vigor, Jackson's daughter, Laura Jackson, a researcher at the University of Northern Iowa, conducted an experiment that showed that a plant need not sacrifice photosynthate—the ability to feed itself—when it puts out lots of seeds. In short, the trade-offs were not as strict as everyone imagined, and it seemed that the chimera The Land Institute wanted to create was well within the realm of the possible.

In 1978, the staff embarked on the painstaking process of breeding crops for the domestic prairie. They would have to possess not only hardiness but also “crop character”—qualities like good taste and ease of threshing. Since the breeding of most of the crops we eat today was fairly well wrapped up by Abraham's time, crop domestication of this sort was a brave new venture. The precedent for this work completely disappears when you consider that Jackson and crew were shooting for crops that were dependable, but *not* dependent on us.

There were two ways they could wind up with a perennial grain—one, they could start with a wild perennial and boost its seed yield and crop character, or two, they could start with an annual that already had good crop character and cross it with a perennial wild relative to refresh its memory about how to survive the winter. Now all they needed were candidates.

Going on catalog descriptions of native perennials in each of the groups, they ordered nearly five thousand different types of seed from governmental seed collections and planted them in the undulating fields by the Smoky Hill River. Those that survived well in Kansas weather and had a whiff of a hope for high seed yield became candidates in their breeding program. They planted the seeds and waited anxiously, as farmers do, to see how the plants matured. Besides seed yield, they were also looking for agronomic characteristics important to a farmer: reduced seed shattering (so seed heads don't break open and spill their grain before harvest), uniform time of maturity, ease of threshing, and large seed size.

The four most promising candidates for perennial domestication turned out to be eastern gamagrass (*Tripsacum dactyloides*), a sprawling warm-season grass that is a relative of corn; Illinois bundleflower (*Desmanthus*

ittinoensis), a legume that grows tall and produces a baby rattle of seed pods; mammoth wildrye (*Leymus racemosus*), a stout cool-season relative of wheat that the Mongols used to feast on when drought claimed their annuals; and Maximilian sunflower (*Helianthus maximiliani*), a composite that yields oil-rich seeds, which could be pressed to create vegetable oil diesel fuel for tractors. The second approach—starting with an annual and hybridizing it with a perennial—led to the mix of milo grain sorghum, which is already used as a crop, and perennial Johnsongrass.

Now that The Land has its lineup, the breeding has begun in earnest. The very best individuals from each species are grown together in one plot so that they can cross-pollinate. When two promising strains “mate,” the hope is that even more bodacious offspring will follow. The seeds from each trial are planted out (in various kinds of soil to make sure the differences are truly genetic, or inheritable, and not just environmental), and the best individuals are selected to cross-pollinate once again. This process is repeated until the improvements due to crossing show signs of diminishing returns. Only then will the breeders call them good and begin the fine-tuning process to bring out each strain’s best features.

So far, optimism at The Land is high, which means a slightly deeper nod from the incredibly modest Jon Piper when I ask whether he’s pleased with their progress. He walks me among the monoculture and polyculture plots where the best of the best are showing their stuff. Some collections of eastern gamagrass are bravely resisting various leaf diseases, and certain collections of bundleflower and gamagrass are yielding well despite some drought. The most vigorous crosses between Johnsongrass and grain sorghum are showing both high seed yield and good rhizome production. (Rhizomes are the underground runners that allow plants to store starch for winter, and thereby survive.)

In terms of seed yield, there are already some superstars. Even though its food value has yet to be explored, says Piper, Illinois bundleflower is yielding seed quantities that approximate the typical yield of nonirrigated soybeans in Kansas. For eastern gamagrass, which can be ground into a cornmeal and baked into a palatable bread, the potential to improve seed yields is great, thanks to a variety that was discovered along a Kansas roadside. The collector noticed that instead of the normal flower stalk, which is composed of about one inch of female flowers topped by four inches of male flowers, this sport had all female parts (which turn into seeds) except at

the very tip. If all yielded, the sport could produce up to four times the normal amount of seeds. As Piper shows me one of the stalks, I notice that the female organs are green. “Exactly,” he says. “That means they can photosynthesize and pay their own bills, meaning the plant won’t necessarily have to trade off fewer roots in order to support more seeds. That’s what we’ll be trying to show.”

By taking on this perennial-grain breeding challenge, folks at The Land Institute were already mucking in that part of the map that warned “serpents lie here.” While they were at it, they thought they’d try for another first by choosing most of their candidates from native stock. (The only plant in their lineup that isn’t native is mammoth wildrye.) Though native stock seems an obvious choice, it hasn’t been to other breeders. Most of our crops are exotics, brought over in our traveling bundles from Mexico and Europe. The only native plants that we have ever domesticated in this country are sunflowers, cranberries, blueberries, pecans, Concord grapes, and Jerusalem artichokes. The Land Institute is trying to lengthen this short list, knowing that natives are tuned through evolution to sing in harmony with the melody of local conditions.

While coaxing agronomic manners from these plants will be a Pygmalion task, growing them in monocultures at least gives breeders a chance to compare apples with apples. Unfortunately, says Jackson, we can’t stay with monocultures. The real Holy Grail is to grow them in *polyculture*—mixed species plots—since, as nature has shown us, only poly cultures are able to pay their own bills.

POLYCULTURE SHOCK

Polyculture is not music to a breeder’s ears. When you are working in a polyculture, you take all the difficulties that you encounter in monoculture breeding and multiply them. You are not only selecting for high yields, large seed size, uniform maturation time, easily threshed seeds, low shattering, winter hardiness, disease and pest resistance, and climate tolerance, but also for compatibility—a plant’s ability to perform well or even exceed performance when grown next to other plants.

The Land Institute staff was essentially faced with designing an agricultural dinner party, deciding who should be seated next to whom to maximize the beneficial interactions and minimize the detrimental ones.

Nature arranges these kinds of matchups all the time through the slow culling of natural selection. Could The Land somehow mimic and speed up this process?

“The traditional scientific method offered one way to go about it,” says Piper, “and we worked this way for a while—planting out seedlings in mixed plots, purposefully putting certain species next to others so we could investigate their interactions.” The problem was that the number of possible combinations is astronomical, and not even a Mendelian monk’s life would be long enough to try them all. Just as Piper and his colleagues started questioning this reductionist approach, they began to read about recent developments in the field of community assembly.

James Drake and Stuart Pimm of the University of Tennessee study what it takes to arrive at an assembly of species that remain in equilibrium, a condition farmers would obviously want for their domestic prairie. Unlike The Land staff, they do their experiments with ecosystems in a computer (artificial life) and with aquatic organisms in glass tanks (real life). They begin by adding species in various combinations and then letting them work out who will survive and in what ratio. Eventually, without intervention, the community shakes down into something that is both complex and persistent—order for free. “But we don’t get order immediately,” says Pimm. “We get it after a long period of adding species to communities and watching them come in, displace other species, and go extinct in their turn.” In other words, having a history is what makes a community last.

In his famous “Humpty Dumpty” hypothesis, Pimm maintains that once you destroy a finished product of community assembly, such as a prairie, you can’t just plant those same species and expect to put it back together again. There’s no such thing as an instant prairie. A prairie restorationist must give the prairie a successional history, that is, actually grow the prairie over a trajectory of years. Some plants will blow in and others will drop out, but as those facilitating species change the soil and the fauna and flora around them, they *make it possible for the final assembly to be there*. They warm up the crowd for the real act.

“The question for us mortal scientists,” says the understated Piper, “and for farmers who will someday grow diverse perennial grains, is how to get that order quickly. We’re not in the business of creating prairies over a thousand years. What we want to do is build complex, persistent systems that shake down within a very few years.”

Nor do they have a thousand years to do the research. What Piper and company have decided to try, in addition to their more reductionist experiments, is a “shakedown” like those that occur in Pimm’s and Drake’s experiments. First, they laid out sixteen plots (sixteen meters by sixteen meters), then randomly broadcast seeds that represented the prairie’s four “suits”: warm-season grasses, cool-season grasses, legumes, and composites. In some plots they sowed only four species, in others eight, twelve, and sixteen. There are four replicates of each treatment. Half of the plots are being left alone to develop as they will, and the other half are called “replacement” plots. After two years, any species in the replacement plots that have dropped out or failed to germinate will be replaced. “We want to give our target species every opportunity to join the community,” says Piper. “It may be that mammoth wildrye can’t establish itself in the first year or the second year, but it can in the third.”

They’ll keep track of which species comes on line when, and which of the plots leads to their desired community first. All the while they will be tracking changes in the communities and looking for rules and patterns about how stable communities assemble. Within a few growing seasons, they want their target perennial grains to be well represented, and to yield abundantly year after year without weeding or seeding. If a few other noncrop species are present in the mix, so be it. “If a plant is consistently present, it probably plays a role in maintaining stability,” says Piper. Eventually, the “recipe” or trajectory the researchers discover will be something they can offer to farmers.

Though they don’t know all the particulars, Piper thinks a typical recipe may work like this: You throw in the recommended mix of species (more than you need), making sure that all important plant groups are represented. Then you sit back and watch the trajectory unfold. The trajectory might take five years, say, but you would be rewarded with a complex, persistent system.

“Right now, for instance, we’re seeing a flush of annual weeds the first and second year. The fields look awful at first, like a total failure, but the perennial seeds are in there and by the second or third year, they just go *whoosh* and come into their own. Somehow, the environment filters out what works from what doesn’t work, so you are left with the most stable combination. We’re studying how this happens, and what steps we might take to help it to happen.” As their plots mature, The Land Institute will be experimenting with various management techniques to favor perennial grains

and to get the community to gel. The resultant recipe might include a recommendation to burn in year two, mow in year three, or graze livestock in year four. They'll also be thinking about the equipment that will be needed to harvest the different crops at different times of year.

"Farming with a crowd of perennials is going to be different," says Piper. "It'll be more like forestry in that you have to wait a while to get to a harvestable stage. Also as with forestry, you can't just start over each year. You can't decide to grow another crop because pests are bad or the weather doesn't cooperate. Instead, you'll have to plan up front for multiyear conditions—weather, markets, et cetera. Your best hedge against disaster is going to be variety, just as the prairie teaches—lots of paints in your palette so that no matter what the conditions, some species will still flourish."

Besides getting the domestic prairie to take, visionaries at The Land also want it to fulfill its promise agriculturally. It has to compete reasonably well with what farmers are now growing. The final three questions that occupy Piper and company have to do with the polyculture performance from that pragmatic point of view.

Can the polyculture yields stay even with or actually overyield those of monocultures?

Overyielding is the phenomenon by which a crop yields more per unit acre when it's growing in a polyculture than when it's in a monoculture. Turns out that plants grown next to different but complementary neighbors don't have to compete the way they do when grown next to an identical plant. They're not jostling root elbows for the water in a particular level, for instance. Nor are they competing for the same plane of sunshine. As a result, the members of a diverse community are actually capturing more resources (and yielding more) than they would under constant same-species competition.

The literature is replete with examples of overyielding when complementary annuals such as maize, beans, and squash are planted together. Piper's charge was to show that overyielding could happen with perennials as well. "Sure enough, we're seeing it," he says, letting a grin escape with this news. "Nineteen ninety-five was the fifth year of a study of polycultures of eastern gamagrass, wildrye, and Illinois bundleflower. When compared with their performances in monoculture, plants in mixtures have consistently overyielded."

Can the polyculture defend itself against insects, pests, and weeds?

Studies at The Land are showing that when plants are grown in bicultures and tricultures, they're better able to fight off insects and diseases than when they're grown in monocultures. It makes sense if you think about it. Plants defend themselves against insects with chemical "locks," and at most, an insect carries only one or two "keys" to the plants it is adapted to eat. An insect that finds itself in a field of nothing but its target plant is like a burglar with the key to every house in the neighborhood. In a polyculture, where all the locks are different, finding food is more of a chore. A mixed neighborhood is equally frustrating for diseases that specialize in one plant. A fungus may fester on an individual, but when it releases its spores, the leaves of invulnerable plants act as a flypaper, bringing the fungal rampage to a halt. That's why, although pests exist in prairie polycultures, you don't see the runaway decimation that you see in monocultures. Invasions are contained.

Just as with overyielding, most of the experimental evidence for resistance comes from studies on annual plants in polycultures. In 1983, Cornell biologists Steve Risch, Dave Andow, and Miguel Altieri reviewed 150 such studies and found that 53 percent of the insect pest species were less abundant in annual polycultures than in annual monocultures. Similarly, Australian ecologist Jeremy Burdon summarized 100 studies of two-component mixtures and found that there were always fewer diseased plants in the polyculture. So far, the same seems to hold true for the perennial polycultures planted at The Land. "In the third year of testing," says Piper, "we had a sudden buildup of beetles on bundleflower. But only in the monocultures. The bundleflower that was grown with gamagrass was fine. Polycultures also seem to reduce or delay the onset of maize dwarf mosaic virus, which can be a problem on eastern gamagrass." Farmers are especially intrigued by these results, since they seem to indicate that pesticides could be scaled back or even eliminated in polycultures. With the thought of pesticides gone, Piper and his colleagues began fantasizing about eliminating another petroleum-based crutch: nitrogen fertilizer.

Can the polyculture sponsor its own nitrogen fertility?

The question of how much nitrogen fertilizer a domestic prairie would need has not been definitively answered as of this writing. So far, though, signs are pointing to little or none. In experiments conducted with annuals, soil fertility always looks stronger in a polyculture, especially when legumes are in the plot. Tiny balls on the roots of a legume (such as Illinois

bundleflower) are home to bacteria that have the ability to turn atmospheric nitrogen into plant food. As a result, legumes find a niche in nitrogen-poor soils, thriving where other plants falter. Plants growing near the self-sufficient legumes may also benefit from stored nitrates that return to the soil when the legume sheds a leaf, turns over a portion of its roots, or lays down its last.

In initial investigations of polycultures that include Illinois bundleflower, Piper found that, as predicted, bundleflower can grow beautifully and yield well even in poor soil, leaving the soil character actually improved. As Piper relates in scientific papers, “The soil nitrate concentration in four-year-old Illinois bundleflower stands at the poorer soil site was nearly identical to that on the better soil site despite very different initial nitrogen conditions.” Growing legumes is like having a crop that yields a harvest *and* simultaneously fertilizes your field. Which is why, of course, no prairie would be without them.

Despite the promise of The Land Institute’s work, we’re a long day away from finding gamagrass bread in our local supermarkets—twenty-five to fifty years, if these researchers are the only ones working. “We’re at the Kitty Hawk stage,” says Jackson. “We’ve demonstrated the principles of drag and lift, but we’re not yet ready to fly people across the Atlantic in a Boeing seven-forty-seven.”

They are ready to make some thrilling claims, however. In Eugene, Oregon, I saw Wes Jackson give an audience goosebumps with this statement: “After seventeen years of scientific research in pursuit of answers to four basic biological questions, The Land Institute is ready to formally state that our country *can* build an agriculture based on a fundamentally different paradigm than the one humans have featured for the last eight to ten thousand years.” Never losing his sly farm-boy humor, Jackson waited for the applause to break and then added, “And not only that, but we think it just might solve all manner of marital problems and end sin and death as we know it.” Although the room roared, there was no mistaking the seriousness of what Jackson and his friends had accomplished.

If the eroding Breadbasket is to be transformed by the work at The Land Institute, it will have sweeping repercussions. But our Breadbasket is only one small part of the world’s agricultural land. What Piper and Jackson and the rest would never dream of doing is importing prairie agriculture

everywhere. The natural systems farm, designed in nature's image, would not look the same in all corners of the world, because ecosystems differ so drastically across the globe. "Take the difference between tropical rain forests and prairies," says Jackson. "In the moist jungle, where water can be too abundant, you want water purgers—plants that can give off water vapor quickly. In the droughty plains, you want water hoarders."

In short, the *genius loci*—"genius of the place"—should dictate the best agricultural system, given the local plant community, climate, soil type, and culture.

What *can* be imported from The Land Institute, Jackson says, is its methodology—its approach to learning a native system, intuiting its "rules," and then slowly trying to raise a stable community of crops that mimics the structure and performs the functions of the wild one. As the following stories will show, the investigation is already under way.

RIPENING PROOF AROUND THE WORLD

"Do Nothing" Farming in Japan

Fifty years ago, when Wes Jackson was a boy weeding his family's farm, a young man in Japan named Masanobu Fukuoka took a walk that would change his life. As he strolled along a rural road, he spotted a rice plant in a ditch, a volunteer growing not from a clean slate of soil but from a tangle of fallen rice stalks. Fukuoka was impressed by the plant's vigor and by the fact that it was up earlier than those in all the surrounding cultivated fields. He took it to be the whisper of a secret revealed to him.

Over the years, Fukuoka would turn this secret into a system he calls "do nothing" farming because it requires almost no labor on his part, and yet his yields are among the highest in Japan. His recipe, fine-tuned through trial and error, mimics nature's trick of succession and soil covering. In early October, Fukuoka hand-sows clover seeds into his standing rice crop. Shortly after that, he sows seeds of rye and barley into the rice. (He coats the seeds with clay so they won't be eaten by birds.) When the rice is ready for harvest, he cuts it, threshes it, and then throws the straw back over the field. By this time, clover is already well established, helping to smother weeds and fix nitrogen in the soil. Through the tangle of clover and straw, rye and barley burst up and begin their climb toward the sun. Just before he harvests the rye and

barley, he starts the cycle again, tossing in rice seeds to start their protected ascent. On and on the cycle goes, self-fertilizing and self-cultivating. In this way rice and winter grains can be grown in the same field for many years without diminishing soil fertility.

The neighboring farmers are curious. Whereas they spend their days cultivating, weeding, and fertilizing, Fukuoka lets the straw and clover do the work. Instead of flooding his fields throughout the season, Fukuoka uses only a brief dousing of water to head off weed germination. After that he drains the fields and then worries about nothing, except an occasional mowing of the paths between fields. On a quarter acre, he will reap twenty-two bushels of rice and twenty-two bushels of winter grains. That's enough to feed five to ten people, yet it takes only one or two people a few days of work to hand-sow and harvest the crop.

Natural farming has spread throughout Japan and is being used on about 1 million acres in China. People from around the world now visit Fukuoka's farm to learn both farming techniques and philosophies. The allure of this system is that the same piece of ground can be used without being used up, and yields can be consistently good. Instead of pouring money and energy into the farm in the form of petroleum-based inputs, most of the investment is made up front—in the farm's design.

"It took me thirty years to develop such simplicity," says Fukuoka. Instead of working harder, he whittled away unnecessary agricultural practices one by one, asking what he could *stop* doing rather than what he could do. Forsaking reliance on human cleverness, he joined in alliance with nature's wisdom. As he says in his book, *One Straw Revolution*, "This method completely contradicts modern agricultural techniques. It throws scientific and traditional farming know-how right out the window. With this kind of farming, which uses no machines, no prepared fertilizer, and no chemicals, it is possible to attain a harvest equal to or greater than that of the average Japanese farm. The proof is ripening right before your eyes."

Permaculture Down Under

When ecosystems are efficient and stable, they don't require as much work as those kept in the vulnerable first stage of succession. Australian ecologist Bill Mollison, like Wes Jackson, advocates keeping some crops on the land for many years, to bring farming as close as it can come to nature's efficiency.

For years, Mollison has worked on perfecting a system whereby small-scale farmers would set up a low-maintenance garden, a woodland, and an animal and fish farm and then become self-sufficient—fed, clothed, and powered by local resources that are literally right at hand. Designing *with* nature's wisdom is at the core of this farming philosophy, which is called permaculture, for permanent agriculture. In permaculture, you ask not what you can wring from the land, but what the land has to offer. You roll with the weaknesses and the strengths of your acreage, and in this spirit of cooperation, says Mollison, the land yields generously without depletion and without inordinate amounts of body work from you. The most laborious part of permaculture is designing the system to be self-supporting.

The idea is to lay out crops so that those you visit most frequently are close by your dwelling (Mollison calls it edible landscaping) and those that require less vigilance are set out in concentric circles farther from the house. Everywhere, there are plants in two-or three-canopy schemes, that is, shrubs shaded by small trees, which are shaded by larger trees. Animals graze beneath all three canopies. Dips and furrows in the land are used to cache rainwater and to irrigate automatically. Wherever possible, permaculturists invite external forces such as wind or flooding to actually help do the work. They build windmills, for instance, or plant crops on floodplains, where they can enjoy a yearly pulse of alluvial sediment.

Choosing synergistic planting arrangements—using “companion plants” to complement and bring out the best in one another—is key to a successful agriscape. To maximize these beneficial unions, the permaculturist creates a lot of edge—transition zones between two habitats that are notoriously full of life and interaction. Mollison is also fond of using interactions between animals in place of high-energy inputs or machinery. One example is a greenhouse/chicken coop where plants are stacked on stair-stepped benches. The chickens roost on the benches at night, enjoying the warmth left over from the day's solar radiation. They add to the heat with their own bodies, helping the plants survive the frosty dawns. In the morning, when the greenhouse becomes too hot, the chickens move into the forest for grazing. As they search for nuts and acorns shed by the planted trees, they comb the ground like rakes, aerating and manuring the soil while snatching up tree pests. Humans eat the eggs and eventually the flesh of these chickens, but in the meantime, they enjoy their services as cultivators, pest controllers, greenhouse heaters, and self-fed fertilizers.

Mollison learned this ballet of efficiency firsthand when he worked in the forests of Australia in the late sixties. As a researcher, he was trained to describe the biological world and leave it at that. But Mollison took the next step that is crucial in biomimicry: He saw lessons for streamlined living emerging from the forest and vowed to apply them to a new kind of agriculture. Today in Australia many farms are now working according to the permaculture principles he has popularized, and an international permaculture institute, with branches throughout the world, is training people to disseminate the technique. By mirroring nature's most stable and productive communities, and then living right in the middle of them, Mollison believes, human communities can begin to participate in their beauty, harmony, and Earth-sheltering productivity.

New Alchemy Farm on Cape Cod

Another example of ecoculture sprouting in place of agriculture can be found on Cape Cod, at the offices of two of the country's most innovative bioneers, John and Nancy Todd. They formed the New Alchemy Institute in 1969 to design living spaces and food producing systems that would use nature as a model. The forest-in-succession was the conceptual guide for their totally self-sustained farm.

"Conceptually our farm begins at the bottom of the numerous fish ponds, and extends upward through the water to the ground cover formed by the vegetable and forage crop zone where livestock graze. It then rises through the shrub layer to the canopy formed by the trees that produce fruit, nuts, timber, and fodder crops. Following this plan we are hoping to maintain the farm in a dynamic state of ongoing productivity while it continues to evolve ecologically in the direction of a forest," Todd writes in his 1994 book, *From Ecocities to Living Machines*. Like Mollison's permaculture, New Alchemy's farm is designed so that every living component has a multiple function—shading and fertilizing, for instance, as well as yielding an edible harvest. Wherever possible, the work of machines (and, by extension, humans) is replaced by the work of biological organisms or systems.

One of the Todds' inspirations was Javan farms in Indonesia, where unconventional (to us, anyway) agriculture has thrived for centuries. The Javanese farm is nature in miniature, and it shows the restorative processes of planned succession. "Successional or ecological agriculture differs from ordinary farming in that it adapts to changes over time. In early phases,

annual crops and fish ponds might dominate the landscape, but as the landscape grows and matures, a third dimension develops as tree crops and livestock come into their own. The key is to mirror the natural tendency of succession which, over time, creates ecosystems that are effective and stable utilizers of space, energy, and biotic elements.”

Three-Story Farming in Costa Rica

Succession is also at the heart of a Costa Rican version of Natural Systems Agriculture. The tropical forests here are paradises—cornucopias of irrepressible vegetation and edible foods ripening under a natural heat lamp and mister. It’s therefore all the more ironic, and perhaps telling, that jungles like this have made such poor sites for growing conventional crops. The first few years after clear-cutting and/or burning a primary forest, crop yields are good, but then they drop precipitously. It makes sense if you realize that the same force that creates the jungle—deluges of rain—can also leach nutrients from unprotected jungle soil after clearing, when there are no plants around to soak up water. Crop harvests also remove even more nutrients from the site. After a few years of this nutrient extortion, the soil quickly tires.

Natural clearings in the jungle meet an entirely different fate. They are quickly revegetated by a parade of species that take over one after another, sinking roots, spreading canopies, shedding leaves, and restoring fertility to the site. Nutrients in the system are kept in play in the green growing biomass—nutrients “on the stump.”

John J. Ewel, a botany professor at the University of Florida, Gainesville, hypothesized that if you could simulate a natural regrowth of jungle using domestic crops as stand-ins for the wild species, you could achieve the same fertility-building phenomenon and actually improve the system rather than deplete it. The trick is to start with crops that mimic the first successional stage (grasses and legumes), and then add crops that mimic the next stage (perennial shrubs), all the way up to the larger trees—nut crops, for instance.

To test their hypothesis, Jack Ewel and colleague Corey Berish cleared two plots in Costa Rica, letting them naturally reseed to jungle. In one of the plots, every time a jungle plant sprouted, they would dig it up and replace it with a human food crop that had the same physical form. Annual for annual, herbaceous perennial for herbaceous perennial, tree for tree, vine for vine—it was as if nature were guiding the hands of the agronomists. The parade of

volunteers to the natural system (*Heliconia* species, cucurbitaceous vines, *Ipomoea* species, legume vines, shrubs, grasses, and small trees) were replaced by plantain, squash varieties, yam, and (by the second or third year) fast-growing nut, fruit, and timber trees such as Brazil nuts, peach, palm, and rosewood.

This domestic jungle of crops looked and behaved like the real jungle in the plot next door. Both plots had similar fine root surface area and identical soil fertility. The researchers also put in two control plots: a bare soil plot and a plot planted in a rotating monoculture—maize and beans followed by cassava, followed by a timber crop. While the bare soil and the rotating monoculture lost their nutrients very rapidly, the “domestic jungle” remained fertile.

Several years before Ewel’s paper came out, British permaculturalist Robert Hart also published some concrete recommendations for cropping systems that would mimic the jungle ecosystem. They included cassava, banana, coconut, cacao, rubber, and lumber crops such as *Cordia* species and *Swietenia* species. At the end of its succession, Hart’s cropping system would be a three-tiered canopy, mimicking the structure of the jungle as well as its nutrient cycling, natural pest control, and water-purging function. The trick to keeping the soil fertile, says Hart, is to choose perennial crops with lots of leaves and roots, so they can protect the soil from hard rains, store nutrients in biomass, and put organic matter back into the soil when they shed. Hart also found it important to use plants that form symbiotic associations, as well as deep-rooted plants that pumped nutrients from different depths of the soil. In this way, the ground was kept continually covered, yields were provided throughout the year, and each set of new crops prepared the soil physically and even chemically for the next stage. Once the succession progressed to tree crops, farmers could selectively harvest timber and burn the perennials every few years to start the cycle again. Besides supporting local farmers, this sustained usefulness may also help to slow the relentless clearing of primary jungle.

The New England Hardwood Forest

Radical as it seems now, mirroring ecosystems is not a new concept. Sir Alfred Howard, whom many credit with the invention of organic agriculture, talked about farming to fit the land in his 1943 book, *An Agricultural Testament*, as did J. Russell Smith, in his 1953 book, *Tree Crops: A*

Permanent Agriculture. Smith wanted to see eastern hillsides replanted with tree crops, which seemed to suit the hills better than the erosion-causing row crops planted after the great green wall of New World forest was torn down.

Smith looked to the eastern deciduous forest as a model of diversity and stability. He described the great number of niches provided by the various tree-canopy levels as well as shrubby and herbaceous understories. Thanks to the diversity, he wrote, pests are kept under control and birds and browsing animals are given many places to make a living. Fine fibrous roots of woody understory plants act like a prairie's sod to hold soil and retain nutrients. Fallen leaves and debris are slowly and steadily recycled into new plant life, preventing leaching and downslope loss of critical nutrients. The organic litter also encourages the growth of mycorrhiza—fungi that form associations with roots and further extend their water-searching power. Every now and then, wind or disease or lightning takes out a tree, creating a gap where succession and renewal can begin again.

Early agriculture on these soils, practiced by Native Americans, was also successional in nature. The tribes practiced small-patch agriculture, raising beans, squash, corn, and tobacco on twenty-to two-hundred-acre plots. After eight to ten years, the native farmers would move on and allow the land to lie fallow. In the twenty-year hiatus before the farmers returned, succession would resume and fertility would be restored. This shifting method required tribes to be nomadic, but it mimicked the natural forest dynamism by creating small patches that were allowed to revert to forest.

In his book, Smith bemoaned the loss of soils and productivity that occurred when white settlers began to farm more permanently on these sites, deforesting hillsides and planting row crops. The farming didn't fit the land, he claimed. Instead, he proposed planting structural analogues—nut-and fruit-bearing trees as the only fitting crops for forest-growing land. One scheme that bore out his dream was a farm of honey locust trees (which bore seed crops) with an understory of Chinese bush clover (a perennial legume suitable for grazing and haying). This system yielded crops and supported animals, all with minimal labor, low management costs, and good weed control. He reported returns of 4,500 pounds of hay per acre per year, 2,920 pounds of honey locust nuts per acre per year on average, with a peak of 8,750 pounds of nuts per acre in eight-year-old trees.

The features that made the hardwood forest sustainable in the wild were repeated here: a tree crop in the overstory, a stable understory to protect the