

# Our Good Earth

The future rests on the soil beneath our feet

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By Charles C. Mann

On a warm September day, farmers from all over the state gather around the enormous machines. Combines, balers, rippers, cultivators, diskers, tractors of every variety—all can be found at the annual Wisconsin Farm Technology Days show. But the stars of the show are the great harvesters, looming over the crowd. They have names like hot rods—the Claas Jaguar 970, the Krone BiG X 1000—and are painted with colors bright as fireworks. The machines weigh 15 tons apiece and have tires tall as a tall man. When I visited Wisconsin Farm Technology Days last year, John Deere was letting visitors test its 8530 tractor, an electromechanical marvel so sophisticated that I had no idea how to operate it. Not to worry: The tractor drove itself, navigating by satellite. I sat high and happy in the air-conditioned bridge, while beneath my feet vast wheels rolled over the earth.

The farmers grin as they watch the machines thunder through the cornfields. In the long run, though, they may be destroying their livelihoods. Midwestern topsoil, some of the finest cropland in the world, is made up of loose, heterogeneous clumps with plenty of air pockets between them. Big, heavy machines like the harvesters mash wet soil into an undifferentiated, nigh impenetrable slab—a process called compaction. Roots can't penetrate compacted ground; water can't drain into the earth and instead runs off, causing erosion. And because compaction can occur deep in the ground, it can take decades to reverse. Farm-equipment companies, aware of the problem, put huge tires on their machines to spread out the impact. And farmers are using satellite navigation to confine vehicles to specific paths, leaving the rest of the soil untouched. Nonetheless, this kind of compaction remains a serious issue—at least in nations where farmers can afford \$400,000 harvesters.

Unfortunately, compaction is just one, relatively small piece in a mosaic of interrelated problems afflicting soils all over the planet. In the developing world, far more arable land is being lost to human-induced erosion and desertification, directly affecting the lives of 250 million people. In the first—and still the most comprehensive—study of global soil misuse, scientists at the International Soil Reference and Information Centre (ISRIC) in the Netherlands estimated in 1991 that humankind has degraded more than 7.5 million square miles of land. Our species, in other words, is rapidly trashing an area the size of the United States and Canada combined.

This year food shortages, caused in part by the diminishing quantity and quality of the world's soil (see "[Dirt Poor](#)"), have led to riots in Asia, Africa, and Latin America. By 2030, when today's toddlers have toddlers of their own, 8.3 billion people will walk the Earth; to feed them, the UN Food and Agriculture Organization estimates, farmers will have to grow almost 30 percent more grain than they do now. Connoisseurs of human fecklessness will appreciate that even as humankind is ratcheting up its demands on soil,

we are destroying it faster than ever before. "Taking the long view, we are running out of dirt," says David R. Montgomery, a geologist at the University of Washington in Seattle.

Journalists sometimes describe unsexy subjects as MEGO: My eyes glaze over. Alas, soil degradation is the essence of MEGO. Nonetheless, the stakes—and the opportunities—could hardly be higher, says Rattan Lal, a prominent soil scientist at Ohio State University. Researchers and ordinary farmers around the world are finding that even devastated soils can be restored. The payoff, Lal says, is the chance not only to fight hunger but also to attack problems like water scarcity and even global warming. Indeed, some researchers believe that global warming can be slowed significantly by using vast stores of carbon to reengineer the world's bad soils. "Political stability, environmental quality, hunger, and poverty all have the same root," Lal says. "In the long run, the solution to each is restoring the most basic of all resources, the soil."

When I met Zhang Liubao in his village in central China last fall, he was whacking the eroded terraces of his farm into shape with a shovel—something he'd been doing after every rain for more than 40 years. In the 1960s, Zhang had been sent to the village of Dazhai, 200 miles to the east, to learn the Dazhai Way—an agricultural system China's leaders believed would transform the nation. In Dazhai, Zhang told me proudly, "China learned everything about how to work the land." Which is true, but not, alas, in the way Zhang intended.

Dazhai is in a geological anomaly called the Loess Plateau. For eon upon eon winds have swept across the deserts to the west, blowing grit and sand into central China. The millennia of dust fall have covered the region with vast heaps of packed silt—loess, geologists call it—some of them hundreds of feet deep. China's Loess Plateau is about the size of France, Belgium, and the Netherlands combined. For centuries the silt piles have been washing away into the Yellow River—a natural process that has exacerbated, thanks to the Dazhai Way, into arguably the worst soil erosion problem in the world.

After floods ravaged Dazhai in 1963, the village's Communist Party secretary refused any aid from the state, instead promising to create a newer, more productive village. Harvests soared, and Beijing sent observers to learn how to replicate Dazhai's methods. What they saw was spade-wielding peasants terracing the loess hills from top to bottom, devoting their rest breaks to reading Mao Zedong's little red book of revolutionary proverbs. Delighted by their fervor, Mao bused thousands of village representatives to the settlement, Zhang among them. The atmosphere was cultlike; one group walked for two weeks just to view the calluses on a Dazhai laborer's hands. Mainly Zhang learned there that China needed him to produce grain from every scrap of land. Slogans, ever present in Maoist China, explained how to do it: Move Hills, Fill Gullies, and Create Plains! Destroy Forests, Open Wastelands! In Agriculture, Learn From Dazhai!

Zhang Liubao returned from Dazhai to his home village of Zuitou full of inspiration. Zuitou was so impoverished, he told me, that people ate just one or two good meals a year. Following Zhang's instructions, villagers fanned out, cutting the scrubby trees on the hillsides, slicing the slopes into earthen terraces, and planting millet on every newly

created flat surface. Despite constant hunger, people worked all day and then lit lanterns and worked at night. Ultimately, Zhang said, they increased Zuitou's farmland by "about a fifth"—a lot in a poor place.

Alas, the actual effect was to create a vicious circle, according to Vaclav Smil, a University of Manitoba geographer who has long studied China's environment. Zuitou's terrace walls, made of nothing but packed silt, continually fell apart; hence Zhang's need to constantly shore up collapsing terraces. Even when the terraces didn't erode, rains sluiced away the nutrients and organic matter in the soil. After the initial rise, harvests started dropping. To maintain yields, farmers cleared and terraced new land, which washed away in turn.

The consequences were dire. Declining harvests on worsening soil forced huge numbers of farmers to become migrants. Partly for this reason, Zuitou lost half of its population. "It must be one of the greatest wastes of human labor in history," Smil says. "Tens of millions of people forced to work night and day on projects that a child could have seen were a terrible stupidity. Cutting down trees and planting grain on steep slopes—how could that be a good idea?"

In response, the People's Republic initiated plans to halt deforestation. In 1981 Beijing ordered every able-bodied citizen older than 11 to "plant three to five trees per year" wherever possible. Beijing also initiated what may still be the world's biggest ecological program, the Three Norths project: a 2,800-mile band of trees running like a vast screen across China's north, northeast, and northwest, including the frontier of the Loess Plateau. Scheduled to be complete in 2050, this Green Wall of China will, in theory, slow down the winds that drive desertification and dust storms.

Despite their ambitious scope, these efforts did not directly address the soil degradation that was the legacy of Dazhai. Confronting that head-on was politically difficult: It had to be done without admitting Mao's mistakes. (When I asked local officials and scientists if the "Great Helmsman" had erred, they changed the subject.) Only in the past decade did Beijing chart a new course: replacing the Dazhai Way with what might be called the Gaoxigou Way.

Gaoxigou (Gaoxi Gully) is west of Dazhai, on the other side of the Yellow River. Its 522 inhabitants live in *yaodong*—caves dug like martin nests into the sharp pitches around the village. Beginning in 1953, farmers marched out from Gaoxigou and with heroic effort terraced not mere hillsides but entire mountains, slicing them one after another into hundred-tier wedding cakes iced with fields of millet and sorghum and corn. In a pattern that would become all too familiar, yields went up until sun and rain baked and blasted the soil in the bare terraces. To catch eroding loess, the village built earthen dams across gullies, intending to create new fields as they filled up with silt. But with little vegetation to slow the water, "every rainy season the dams busted," says Fu Mingxing, the regional head of education. Ultimately, he says, villagers realized that "they had to protect the ecosystem, which means the soil."

Today many of the terraces Gaoxigou laboriously hacked out of the loess are reverting to nature. In what locals call the "three-three" system, farmers replanted one-third of their land—the steepest, most erosion-prone slopes—with grass and trees, natural barriers to erosion. They covered another third of the land with harvestable orchards. The final third, mainly plots on the gully floor that have been enriched by earlier erosion, was cropped intensively. By concentrating their limited supplies of fertilizer on that land, farmers were able to raise yields enough to make up for the land they sacrificed, says Jiang Liangbiao, village head of Gaoxigou.

In 1999 Beijing announced it would deploy a Gaoxigou Way across the Loess Plateau. The Sloping Land Conversion Program—known as "grain-for-green"—directs farmers to convert most of their steep fields back to grassland, orchard, or forest, compensating them with an annual delivery of grain and a small cash payment for up to eight years. By 2010 grain-for-green could cover more than 82,000 square miles, much of it on the Loess Plateau.

But the grand schemes proclaimed in faraway Beijing are hard to translate to places like Zuitou. Provincial, county, and village officials are rewarded if they plant the number of trees envisioned in the plan, regardless of whether they have chosen tree species suited to local conditions (or listened to scientists who say that trees are not appropriate for grasslands to begin with). Farmers who reap no benefit from their work have little incentive to take care of the trees they are forced to plant. I saw the entirely predictable result on the back roads two hours north of Gaoxigou: fields of dead trees, planted in small pits shaped like fish scales, lined the roads for miles. "Every year we plant trees," the farmers say, "but no trees survive."

Some farmers in the Loess Plateau complained that the almonds they had been told to plant were now swamping the market. Others grumbled that Beijing's fine plan was being hijacked by local officials who didn't pay farmers their subsidies. Still others didn't know why they were being asked to stop growing millet, or even what the term "erosion" meant. Despite all the injunctions from Beijing, many if not most farmers were continuing to plant on steep slopes. After talking to Zhang Liubao in Zuitou, I watched one of his neighbors pulling turnips from a field so steep that he could barely stand on it. Every time he yanked out a plant, a little wave of soil rolled downhill past his feet.

Sometime in the 1970s, "Sahel" became a watchword for famine, poverty, and environmental waste. Technically, though, the name refers to the semiarid zone between the Sahara desert and the wet forests of central Africa. Until the 1950s the Sahel was thinly settled. But when a population boom began, people started farming the region more intensively. Problems were masked for a long time by an unusual period of high rainfall. But then came drought. The worst effects came in two waves—one in the early 1970s and a second, even more serious, in the early 1980s—and stretched from Mauritania on the Atlantic to Chad, halfway across Africa. More than 100,000 men, women, and children died in the ensuing famine, probably many more.

"If people had the means to leave, they left," says Mathieu Ouédraogo, a development specialist in Burkina Faso, a landlocked nation in the heart of the Sahel. "The only people who stayed here had nothing—not enough to leave."

Scientists still dispute why the Sahel transformed itself from a savanna into a badland. Suggested causes include random changes in sea-surface temperatures, air pollution that causes clouds to form inopportunistically, removal of surface vegetation by farmers moving into the desert periphery—and, of course, global warming. Whatever the cause, the consequences are obvious: Hammered by hot days and harsh winds, much of the soil turns into a stone-hard mass that plant roots and rainwater cannot penetrate. A Sahelian farmer once let me hack at his millet field with a pick. It was like trying to chop up asphalt.

When the drought struck, international aid groups descended on the Sahel by the score. (Ouédraogo, for instance, directed a project for Oxfam in the part of Burkina where he had been born and raised.) Many are still there now; half the signs in Niamey, capital of neighboring Niger, seem to be announcing a new program from the United Nations, a Western government, or a private charity. Among the biggest is the Keita project, established 24 years ago by the Italian government in mountainous central Niger. Its goal: bringing 1,876 square miles of broken, barren earth—now home to 230,000 souls—to ecological, economic, and social health. Italian agronomists and engineers cut 194 miles of road through the slopes, dug 684 wells in the stony land, constructed 52 village schools, and planted more than 18 million trees. With bulldozers and tractors, workers carved 41 dams into the hills to catch water from the summer rains. To cut holes in the ground for tree planting, an Italian named Venanzio Vallerani designed and built two huge plows—"monstrous" was the descriptor used by Amadou Haya, an environmental specialist with the project. Workers hauled the machines to the bare hills, filled their bellies full of fuel, and set them to work. Roaring across the plateaus for months on end, they cut as many as 1,500 holes an hour.

Early one morning Haya took us to a rainwater-storage dam outside the village of Koutki, about 20 minutes down a rutted dirt road from Keita project headquarters. The water, spreading oasis like over several acres, was almost absurdly calm; birds were noisily in evidence. Women waded into the water to fill plastic jerry cans, their brilliant robes floating around their ankles. Twenty-five years ago Koutki was a bit player in the tragedy of the Sahel. Most of its animals had died or been eaten. There was not a scrap of green in sight. No birds sang. People survived on mouthfuls of rice from foreign charities. On the road to Koutki we met a former soldier who had helped distribute the aid. His face froze when he spoke about the starving children he had seen. Today there are barricades of trees to stop the winds, low terraces for planting trees, and lines of stone to interrupt the eroding flow of rainwater. The soil around the dam is still dry and poor, but one can imagine people making a living from it.

Budgeted at more than \$100 million, however, the Keita project is expensive—Niger's per capita income, low even for the Sahel, is less than \$800 a year. Keita boosters can argue that it costs two-thirds of an F-22 fighter jet. But the Sahel is vast—Niger alone is a

thousand miles across. Reclaiming even part of this area would require huge sums if done by Keita methods. In consequence, critics have argued that soil-restoration efforts in the drylands are almost pointless: best turn to more promising ground.

Wrong, says Chris Reij, a geographer at VU (Free University) Amsterdam. Having worked with Sahelian colleagues for more than 30 years, Reij has come to believe that farmers themselves have beaten back the desert in vast areas. "It is one of Africa's greatest ecological success stories," he says, "a model for the rest of the world." But almost nobody outside has paid attention; if soil is MEGO, soil in Africa is MEGO squared.

In Burkina, Mathieu Ouédraogo was there from the beginning. He assembled the farmers in his area, and by 1981 they were experimenting together with techniques to restore the soil, some of them traditions that Ouédraogo had heard about in school. One of them was *cordons pierreux*: long lines of stones, each perhaps the size of a big fist. Snagged by the cordon, rains washing over crusty Sahelian soil pause long enough to percolate. Suspended silt falls to the bottom, along with seeds that sprout in this slightly richer environment. The line of stones becomes a line of plants that slows the water further. More seeds sprout at the upstream edge. Grasses are replaced by shrubs and trees, which enrich the soil with falling leaves. In a few years a simple line of rocks can restore an entire field.

For a time Ouédraogo worked with a farmer named Yacouba Sawadogo. Innovative and independent-minded, he wanted to stay on his farm with his three wives and 31 children. "From my grandfather's grandfather's grandfather, we were always here," he says. Sawadogo, too, laid *cordons pierreux* across his fields. But during the dry season he also hacked thousands of foot-deep holes in his fields—*zai*, as they are called, a technique he had heard about from his parents. Sawadogo salted each pit with manure, which attracted termites. The termites digested the organic matter, making its nutrients more readily available to plants. Equally important, the insects dug channels in the soil. When the rains came, water trickled through the termite holes into the ground. In each hole Sawadogo planted trees. "Without trees, no soil," he says. The trees thrived in the looser, wetter soil in each *zai*. Stone by stone, hole by hole, Sawadogo turned 50 acres of wasteland into the biggest private forest for hundreds of miles.

Using the *zai*, Sawadogo says, he became almost "the only farmer from here to Mali who had any millet." His neighbors, not surprisingly, noticed. Sawadogo formed a *zai* association, which promotes the technique at an annual show in his family compound. Hundreds of farmers have come to watch him hack out *zai* with his hoe. The new techniques, simple and inexpensive, spread far and wide. The more people worked the soil, the richer it became. Higher rainfall was responsible for part of the regrowth (though it never returned to the level of the 1950s). But mostly it was due to millions of men and women intensively working the land.

Last year Reij made a thousand-mile trek across Mali and then into southwestern Burkina with Edwige Botoni, a researcher at the Permanent Interstate Committee for Drought

Control in the Sahel, a regional policy center in Burkina. They saw "millions of hectares" of restored land, Botoni says, "more than I had believed possible." Next door in Niger is an even greater success, says Mahamane Larwanou, a forester at Abdou Moumouni Dioffo University in Niamey. Almost without any support or direction from governments or aid agencies, local farmers have used picks and shovels to regenerate more than 19,000 square miles of land.

Economics as much as ecology is key to Niger's success, Larwanou says. In the 1990s the Niger government, which distributed land in orthodox totalitarian fashion, began to let villagers have more control over their plots. People came to believe that they could invest in their land with little risk that it would be arbitrarily taken away. Combined with techniques like the *zai* and *cordons pierreux*, land reform has helped villagers become less vulnerable to climate fluctuations. Even if there were a severe drought, Larwanou says, Nigeriens "would not feel the impact the way they did in 1973 or 1984."

Burkina Faso has not recovered as much as Niger. Sawadogo's story suggests one reason why. While villagers in Niger have gained control over their land, smallholders in Burkina still lease it, often for no charge, from landowners who can revoke the lease at the end of any term. To provide income for Burkina's cities, the central government let them annex and then sell land on their peripheries—without fairly compensating the people who already lived there. Sawadogo's village is a few miles away from Ouahigouya, a city of 64,000 people. Among the richest properties in Ouahigouya's newly annexed land was Sawadogo's forest, a storehouse of timber. Surveyors went through the property, slicing it into tenth-of-an-acre parcels marked by heavy stakes. As the original owner, Sawadogo will be allotted one parcel; his older children will also each receive land. Everything else will be sold off, probably next year. He watched helplessly as city officials pounded a stake in his bedroom floor. Another lot line cut through his father's grave. Today Yacouba Sawadogo is trying to find enough money to buy the forest in which he has invested his life. Because he has made the land so valuable, the price is impossibly high: about \$20,000. Meanwhile, he tends his trees. "I have enough courage to hope," he says.

Wim Sombroek learned about soil as a child, during the *hongerwinter*—the Dutch wartime famine of 1944-45, in which 20,000 or more people died. His family survived on the harvest from a minute plot of *plaggen* soil: land enriched by generations of careful fertilization. If his ancestors hadn't taken care of their land, he once told me, the whole family might have died.

In the 1950s, early in his career as a soil scientist, Sombroek journeyed to Amazonia. To his amazement, he found pockets of rich, fertile soil. Every Ecology 101 student knows that Amazonian rain forest soils are fragile and impoverished. If farmers cut down the canopy of trees overhead to clear cropland, they expose the earth to the pummeling rain and sun, which quickly wash away its small store of minerals and nutrients and bake what remains into something resembling brick—a "wet desert," as these ruined areas are sometimes called. The certainty of wrecking the land, environmentalists argue, makes large-scale agriculture impossible in the tropics. Nevertheless, scattered along the

Amazon River, Sombroek discovered big patches of (black Indian earth). As lush and dark as the plaggen of his childhood, it formed a rich base for agriculture in a land where it was not supposed to exist. Naturally, Sombroek paid attention. His 1966 book, *Amazon Soils*, included the first sustained study of terra preta.

Later Sombroek worked across the globe, eventually becoming director of ISRIC and secretary general of the International Society of Soil Science (now International Union of Soil Sciences), positions he used to convene the first ever world survey of human-induced soil degradation. All the while he never forgot the strange black earth in Brazil. Most restoration programs, like those in China and the Sahel, try to restore degraded soil to its previous condition. But in much of the tropics, its natural state is marginal—one reason so many tropical countries are poor. Sombroek came to believe that terra preta might show scientists how to make land richer than it ever had been, and thus help the world's most impoverished nations feed themselves.

Sombroek will never see his dream fulfilled—he died in 2003. But he helped to assemble a multinational research collaboration to investigate the origin and function of terra preta. Among its members is Eduardo Góes Neves, a University of São Paulo archaeologist whom I visited not long ago at a papaya plantation about a thousand miles up the Amazon, across the river from the city of Manaus. Beneath the trees was the unmistakable spoor of archaeological investigation: precisely squared off trenches, some of them seven feet deep. In the pits the terra preta, blacker than the blackest coffee, extended from the surface down as much as six feet. Top to bottom, the soil was filled with broken pre-Columbian pottery. It was as if the river's first inhabitants had thrown a huge, rowdy frat party, smashing every plate in sight, then buried the evidence.

Terra preta is found only where people lived, which means that it is an artificial, human-made soil, dating from before the arrival of Europeans. Neves and his colleagues have been trying to find out how the Amazon's peoples made it, and why. The soil is rich in vital minerals such as phosphorus, calcium, zinc, and manganese, which are scarce in most tropical soils. But its most striking ingredient is charcoal—vast quantities of it, the source of terra preta's color. Neves isn't sure whether Indians had stirred the charcoal into the soil deliberately, if they had done it accidentally while disposing of household trash, or even if the terra preta created by charcoal initially had been used for farming. Ultimately, though, it became a resource that could sustain entire settlements; indeed, Neves said, a thousand years ago two Indian groups may have gone to war over control of this terra preta.

Unlike ordinary tropical soils, terra preta remains fertile after centuries of exposure to tropical sun and rain, notes Wenceslau Teixeira, a soil scientist at Embrapa, a network of agricultural research and extension agencies in Brazil. Its remarkable resilience, he says, has been demonstrated at Embrapa's facility in Manaus, where scientists test new crop varieties in replica patches of terra preta. "For 40 years, that's where they tried out rice, corn, manioc, beans, you name it," Teixeira says. "It was all just what you're not supposed to do in the tropics—annual crops, completely exposed to sun and rain. It's as if

we were trying to ruin it, and we haven't succeeded!" Teixeira is now testing terra preta with bananas and other tropical crops.

Sombroek had wondered if modern farmers might create their own terra preta—*terra preta nova*, as he dubbed it. Much as the green revolution dramatically improved the developing world's crops, terra preta could unleash what the scientific journal *Nature* has called a "black revolution" across the broad arc of impoverished soil from Southeast Asia to Africa.

Key to terra preta is charcoal, made by burning plants and refuse at low temperatures. In March a research team led by Christoph Steiner, then of the University of Bayreuth, reported that simply adding crumbled charcoal and condensed smoke to typically bad tropical soils caused an "exponential increase" in the microbial population—kick-starting the underground ecosystem that is critical to fertility. Tropical soils quickly lose microbial richness when converted to agriculture. Charcoal seems to provide habitat for microbes—making a kind of artificial soil within the soil—partly because nutrients bind to the charcoal rather than being washed away. Tests by a U.S.-Brazilian team in 2006 found that terra preta had a far greater number and variety of microorganisms than typical tropical soils—it was literally more alive.

A black revolution might even help combat global warming. Agriculture accounts for more than one-eighth of humankind's production of greenhouse gases. Heavily plowed soil releases carbon dioxide as it exposes once buried organic matter. Sombroek argued that creating terra preta around the world would use so much carbon-rich charcoal that it could more than offset the release of soil carbon into the atmosphere. According to William I. Woods, a geographer and soil scientist at the University of Kansas, charcoal-rich terra preta has 10 or 20 times more carbon than typical tropical soils, and the carbon can be buried much deeper down. Rough calculations show that "the amount of carbon we can put into the soil is staggering," Woods says. Last year Cornell University soil scientist Johannes Lehmann estimated in *Nature* that simply converting residues from commercial forestry, fallow farm fields, and annual crops to charcoal could compensate for about a third of U.S. fossil-fuel emissions. Indeed, Lehmann and two colleagues have argued that humankind's use of fossil fuels worldwide could be wholly offset by storing carbon in terra preta nova.

Such hopes will not be easy to fulfill. Identifying the organisms associated with terra preta will be difficult. And nobody knows for sure how much carbon can be stored in soil—some studies suggest there may be a finite limit. But Woods believes that the odds of a payoff are good. "The world is going to hear a lot more about terra preta," he says.

Walking the roads on the farm hosting Wisconsin Farm Technology Days, it was easy for me to figure out what had worried Jethro Tull. Not Jethro Tull the 1970s rock band—Jethro Tull the agricultural reformer of the 18th century. Under my feet the prairie soil had been squashed by tractors and harvesters into a peculiar surface that felt like the poured-rubber flooring used around swimming pools. It was a modern version of a

phenomenon noted by Tull: When farmers always plow in the same path, the ground becomes "trodden as hard as the Highway by the Cattle that draw the Harrows."

Tull knew the solution: Don't keep plowing in the same path. In fact, farmers are increasingly not using plows at all—a system called no-till farming. But their other machines continue to grow in size and weight. In Europe, soil compaction is thought to affect almost 130,000 square miles of farmland, and one expert suggests that the reduced harvests from compaction cost midwestern farmers in the U.S. \$100 million in lost revenue every year.

The ultimate reason that compaction continues to afflict rich nations is the same reason that other forms of soil degradation afflict poor ones: Political and economic institutions are not set up to pay attention to soils. The Chinese officials who are rewarded for getting trees planted without concern about their survival are little different from the farmers in the Midwest who continue to use huge harvesters because they can't afford the labor to run several smaller machines.

Next to the compacted road on the Wisconsin farm was a demonstration of horse-drawn plowing. The earth curling up from the moldboard was dark, moist, refulgent—perfect midwestern topsoil. Photographer Jim Richardson got on his belly to capture it. He asked me to hunker down and hold a light. Soon we drew a small, puzzled crowd. Someone explained that we were looking at the soil. "What are they doing that for?" one woman asked loudly. In her voice I could hear the thought: MEGO.

When I told this story over the phone to David Montgomery, the University of Washington geologist, I could almost hear him shaking his head. "With eight billion people, we're going to *have* to start getting interested in soil," he said. "We're simply not going to be able to keep treating it like dirt."