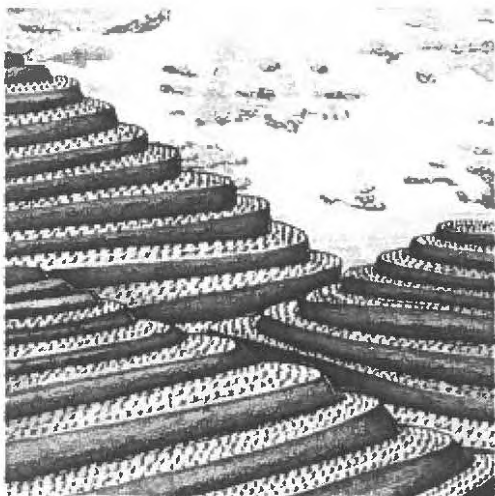


Soil Stewards



Beneath the bustle of cities, towns, farms, forests, and highways lies the silent, dark ribbon of life, rock, and water that binds the past and future. People living in the present hold the power to strengthen or break that bond. The ribbon chronicles our actions, baring them for the future to see. During our brief tenure as custodians of soil, we may nourish it, leaving a better legacy than the one we inherited. Or with neglect and abuse, we fray the ribbon, creating an uncertain future for generations to come and the Earth itself.

Soil legacies often find their origins in cultural values and beliefs. Some cultures treat soil as merely a means to a productive and profitable end. Others honor it as a divine maternal source of all life. For

many, soil seems renewable and limitless, while others view it as a vanishing resource that must be protected. Whatever their beliefs, people throughout history and across the world's cultures have left soil legacies that tell stories. Examining the practices that created strong legacies teaches us how to nurture today's soil so that it lasts until tomorrow. A powerful theme emerges: we know how to do this! For millennia farmers have managed wind, water, and the soil itself to minimize erosion. The practices were refined, mechanized, and quantified in the last century but are not new to the modern age of agriculture.

A comparison of soil management across cultures illuminates a second theme: good soil stewards converge on the same management methods whether they live in the Northern or Southern Hemisphere, grow maize or tef, use planting sticks or spades. Their continued practice of agriculture today is proof that long-lived agrarian societies tend their soil with care. Those that squander soil simply do not survive.¹

When I was first learning soil science, I was overwhelmed by the variety of soils and soil management practices. Wanting to see them all, I imagined having the superpower to fly over the world's landscapes and peer into the underground activity influencing soil health. Today my youthful fantasy is well approximated by a drone or satellite equipped with laser sensors, although drones don't usually accept passengers! But if we could hitch a ride on one of those drones, we would see some astonishing examples of land stewardship—places where humans have cultivated soil richness that far exceeds what was there originally. The resulting soils are Anthrosols, shaped by anthropogenic activity. For example, flying over the tiny island of Papa Stour off the coast of Scotland, we would still see the results of the plaggen agriculture long practiced on many Shetland Islands, first by Norse

settlers around 800 CE and then by the Scottish people. On Papa Stour, agriculture continued until the 1960s, when the island's population declined, reducing the need for food production. Much of the plaggen-influenced agricultural land on Papa Stour has remained uncultivated for the past sixty years, enabling curious scientists and anthropologists to reconstruct the practices that created its signature Anthrosol. For over one thousand years, farmers nourished the land with copious manure, turf, seaweed, and byre muck (the bedding from cow stalls) and worked the soil with spades rather than plows. When they finished farming, the land chronicled a 75-centimeter legacy of topsoil compared with only 16 centimeters in uncultivated surrounding areas. Most farmers in western Europe abandoned plaggen agriculture when the Haber-Bosch process made nitrogen fertilizers readily available, and today their topsoil has been substantially reduced. But the Papa Stour Anthrosol remains as a testament to the ancient practice.²

Underground monuments memorialize the lasting benefits of other past practices. Under the dense forests of South America, for instance, scientists found the soils known as Amazonian Dark Earths. In fact, scientists discovered this Anthrosol in pockets of the Amazon rain forest using a laser much like the one on our fantastical drone.³ These black soils are found in places that were once home to small communities of indigenous people who raised plants for food in the forest. The Amazonian Dark Earths contain deep stores of organic matter deposited by cool burns that produced biochar. People enriched the soil further with plant waste dropped in the town dump, which generated great compost. The residue of biochar and compost still freckles the forested landscape. Its richness contrasts sharply with the surrounding thin tropical soil, making it easily detectable by lasers even centuries after the land was abandoned to the jungle.

If our drone took us northward from the Amazon to Xochimilco,

just south of Mexico City, we would catch sight of chinampas, or artificial floating gardens, which some historians believe enabled the Aztecs to build their great empire. The farming technique traces back to pre-Aztec Mesoamerica between 800 and 1000 CE; later the Aztecs launched massive canal construction projects, expanding chinampa food production to meet the needs of their population of five to six million. Chinampa technology hasn't changed much in over one thousand years—mud from the bottom of lakes and canals is combined with peat from land to build up piles of the jet-black mixture that reach from the bottom of the waterway to the surface. Although they are still referred to as floating, the islands are in fact anchored to the bottom of the waterways. The surfaces of the islands display a dark Anthrosol that is held firmly in place by vegetation bordering the islands, preventing erosion into the canals. Only 10 meters wide but stretching several kilometers, these long, skinny islands carve the canals into narrow channels. The artificial islands are a remarkable example of human ingenuity. The soil on the chinampas continues to support productive agriculture—farmers raise fruits, vegetables, and flowers throughout the 406 kilometers of canals. The islands add 2,000 hectares to Mexico's farmland, supplying organic produce for twelve thousand people in Mexico City and supporting 11 percent of Mexico's biological diversity.⁴

Moving eastward to the Philippines' Cordillera Central region on the island of Luzon, we would see just over 17,000 hectares of land, much of which has been farmed for two thousand years by the Ifugao people. They continue to manage their land with a traditional, highly structured system of forests, farms, rice terraces, and settlements. The land flaunts lush terraces that encircle mountains too steep to farm without recontouring (see pl. 7 for terraces). The Ifugaos' farming methods mold this rugged terrain, enabling it to withstand the high-intensity 320 centimeters of annual rainfall it receives. Only adher-

ence to long-tested methods to reduce water velocity and trap sediment enables them to keep erosion at 0.068 tonnes per hectare per year—a remarkable feat, given that nearby untended land erodes on average more than 24 tonnes per hectare per year.⁵ Thousands of years of successful agriculture attest to the effectiveness of the Ifugao system for building a stable agroecosystem on carefully tended soil.

Farming outcomes are typically invisible because they lie beneath the opaque skin of the Earth, but sometimes remote sensing detects differences in surface color or elevation that indicate deeper impacts. These ancient soil relics reveal a treasure trove of innovations that improve soil quality and prevent its loss. Let's now end our drone flight of fantasy and turn to the task of identifying scientific elements inherent in great soil stewardship.

There are two universal principles in preventing erosion: first, manage the forces that move soil; second, improve soil structure. Since wind and water drive erosion, any intervention that reduces their velocity also reduces erosion, as do the Ifugaos' terraces. Just as important as managing the forces that transport soil is building the soil from within—improving its architecture by binding separate particles into aggregates that are more difficult to propel. Aggregation is promoted by deep-rooted perennial plants, cover crops, and crop rotations, all of which enhance the soil's microbiome and organic matter.⁶ As the Amazon forest and Papa Stour illustrate, farmers can create productive Anthrosols with crop residue, manure, biochar, compost, and other amendments that increase soil organic matter, which in turn promotes aggregate formation, reducing erodibility. And good soil stewards protect soil structure by minimizing plowing.

Where did these practices originate, and what can we learn from them? Probing the methods that have enabled people to triumph over erosion since the beginning of agrarian life builds an appreciation of

the diversity, simplicity, and power of soil-protective farming practices. Indigenous knowledge has been subjected to the harsh selective forces of the world, a process of sifting and winnowing to continue practices that work and discard those that don't. The body of knowledge held by the world's 350 million indigenous people is much larger than their population.⁷ The details of indigenous practices offer complex, nuanced lessons for all agriculturalists.

Given their many achievements, it should be no surprise that the ancient Maya developed sophisticated methods of soil stewardship. For nearly four thousand years Maya civilization sprawled across the Yucatán Peninsula on land that includes parts of modern-day Mexico, Guatemala, Belize, El Salvador, and Honduras. The population is thought to have declined after 900 CE, and the Maya battled colonial invaders for years after the Spaniards' arrival in 1502, but tenacious Maya farmers continue their traditional agricultural practices today. They are both inspiring and enlightening.

Scientists have gleaned knowledge of the ancient Maya from archaeology and from the soil itself. Murals decorating ancient walls and ceilings still flaunt vivid red, turquoise, orange, brown, and green pigments depicting in exquisite detail Maya government, religion, and celebrations that inform us about their agriculture. The Maya also left behind records in intricate hieroglyphics that still have not been fully deciphered. They applied their renowned arithmetic prowess and study of the cycles of the natural world to create a calendar system to synchronize agricultural operations around the wet and dry seasons. They followed the solar cycle with technology that captured the angle of the sun, a challenging task in a nearly equatorial location.⁸

The abundance of Maya agriculture is indicated by evidence of stockpiles and a social system to distribute excess. Their cropping system centers around maize, which was domesticated from a wild plant

in the lowlands of western Mexico around 7000 BCE.⁹ In the case of maize, we have clear genetic evidence of the domestication process, which involved selecting plants that conformed to the agricultural system and yielded useful food. High-producing maize supported development of settlements, villages, and cities along with food stockpiles. The Maya included as many as seven other plant species in their cropping system, which was part of the secret to their continuous productivity and soil protection. Maya agriculture enabled rapid growth of the population and emergence of their complex, sophisticated society.

Much has been made of the Maya collapse, a purported decline in population from six million to five hundred thousand starting in 900 CE. The reasons for the decline remain unclear, and like so many gargantuan historical shifts, it was likely caused by several factors that undoubtedly differed over space and time. Analysis of tree rings and radioisotopes suggests that the Maya were confronted with prolonged drought around the year 900. Some historians have documented a concurrent reduction of food stockpiles, suggesting that agricultural production declined with water availability; others dispute this and say that there is no evidence of food shortages. A 2020 study reported high levels of mercury in the reservoirs surrounding the palace and temples in Tikal, once a Maya metropolis. Along with the mercury, the reservoirs also contained DNA signatures of cyanobacterial species—producers of potent toxins that still plague water systems today. Contaminated water might have contributed to diminishing the population. Some scholars say that there was never a precipitous decline but rather a gradual change over hundreds of years accompanied by changes in climate, governance, and societal organization. Yet despite all of these possibly contributing factors, soil erosion has been blamed for the decline of food abundance and with it the population, so the Maya might seem like an odd choice to illustrate sustainable farming

practices.¹⁰ But a close study tells instead a tale of extraordinary soil stewardship that sustained the rich Maya culture and its people for thousands of years. Their sophisticated agricultural system has much to teach farmers worldwide.

Some historians have condemned Maya agriculture as classic slash and burn, which involves clearing forests with fire, planting crops for a few years, depleting the limited fertility deposited as ash and charcoal, and abandoning the land. Those historians were greatly mistaken about Maya agriculture. Study of their farming system led to renaming it swidden agriculture, because it uses cool fires that produce biochar, similar to the process that led to the Amazon Dark Earths. Biochar from the Maya forest burns provides soil nourishment, whereas slash and burn typically uses hotter fires, which volatilize organic matter rather than storing it in the soil. In fact, few cultures take such a long view of soil health—the Maya developed a complex agricultural sequence, known as the milpa system or milpa forest gardens, that follows ten- to twenty-five-year cycles. The typical milpa garden intersperses corn, squash, and beans or any of the other seventy food species the Maya use in the rotation. The plant diversity nourishes the soil and provides a rich diet for people. After four years, when crop growth reduces soil fertility and perennial plants become dominant, the Maya cultivate a mixture of tree and shrub species that provide nuts, fruits, cacao, medicinal plants, and building materials. The reforested patch of land is maintained for about twenty years before repeating the cycle. The combination of trees and shrubs creates a balanced ecosystem. Trees capture copious carbon through photosynthesis, replenishing soil organic matter, and retrieve leached nutrients from soil depths inaccessible to smaller plant species. When the trees burn, they once again deposit nutrients in charcoal and ash in the upper horizons that are made available for the next cropping sequence.¹¹ With several gardens managed asynchronously

and simultaneously, there are always some producing the staple crops, such as maize, while others are maintained in a restorative phase, producing other necessary forest products.

How ironic that historians have dismissed Maya agriculture as soil-destroying, whereas in reality, the rigorous planting sequence in the milpa gardens is an example of a highly effective regime to *maintain* soil health. Many historians cling to the storyline that soil erosion caused the Maya decline, even to the point of arguing that contemporary Maya are repeating the sins of a thousand years ago using as evidence Landsat 4 satellite images that show deforestation in regions the Maya inhabit. Yet those same images are known to be in locations where cattle pastures replaced forest. The flaw with their argument is that the Maya did not pasture animals one thousand years ago! Instead, they hunted wild mammals and birds in the forest. Today's deforestation does not provide relevant evidence about the purported Maya collapse.¹²

Many Maya-cultivated tree species persist today in the remnants of their forests, which are as much a Maya legacy as their temples and monuments.¹³ The Maya choose trees for the overstory and plants for the understory based on utility and rapid growth, which helps to crowd out weeds. The system works superbly, but it is labor-intensive—requiring seed collection, hand weed management, and burning. Successful milpa gardens rely on knowledge, skill, and labor. Today many farmers lack the labor and time to invest in hand weeding and reforesting gardens, so they resort to labor-saving practices such as herbicide application, which has been accompanied by a loss of almost 20 centimeters of soil in just four years, stripping most of the topsoil. When nutrients are not replenished by two decades of forest growth, these sites become infertile.¹⁴

Lake Salpetén in Guatemala contains clay sediments that soil scientists have interpreted as indicating three waves of soil erosion during

the period of Maya prominence in Mesoamerica. The first two coincided with bursts of expansion of land clearing for new milpa forest gardens. When the forests were burned on virgin land, there may have been immediate soil loss, but the land gradually recovered as the meticulously managed milpa gardens rebuilt a thick soil layer.¹⁵ For almost three thousand years, traditional milpa sustained a growing population on its rich soil substrate. Today's Maya steward soil carefully and demonstrate the beauty of the milpa gardens for growing food in harmony with soil and the broader ecosystem, so it is difficult to reconcile 7 meters of lake sediment derived from agricultural soil with the care and attention the Maya pay to their soil.

The sophisticated soil stewardship of the early Maya adhered to the two principles of erosion prevention: managing wind and water as well as the soil itself. Most of their soil management was embodied in the milpa garden design, which provided plant diversity, good land cover, protection of soil structure with planting sticks rather than plows, and rotation inherent in the garden cycle. In the limited land area where they encountered swampy lowlands they built canals and raised beds to protect the land from flooding, and on slopes they installed terraces to reduce the likelihood of gravity and water washing soil away. Modern remote-sensing technology, which penetrates the dense forest cover that had prevented previous detection, revealed intricate networks of terraces and drainage systems, relics of Maya innovation.¹⁶ Even today, terraces built over one thousand years ago hold three to four times as much soil as nearby untterraced land. To satisfy the second principle of erosion prevention, Maya farmers work to enrich their soil, boosting carbon by deploying deep-rooted perennials, compost, and copious biochar. These practices, combined with the absence of plowing, built and maintained robust soil structure that countered erosive forces.

Today in the Lacandon rain forest near the Mexico-Guatemala

border, fewer than two thousand Lacandon Maya preserve the language and culture. They live among five hundred thousand indigenous people, mainly of Maya descent, continuing to raise food in traditional milpa gardens with a great diversity of plant species and long periods of soil regeneration. The Lacandones who survived both the Maya population decline and subsequent brutal colonization by European invaders demonstrate the sustainability of traditional Maya farming methods, but the community continues to battle for its existence. Intruders abuse the land by clearing forests, monocropping, and introducing cattle grazing that together destroy both the rain forest and the soil. The indigenous group is also under siege from the Mexican government, which offers monetary incentives to deter the Lacandones from burning forests in the milpa cycle, based on a misguided assumption that all burning is destructive. Ironically, without managed burns, the forests are vulnerable to spontaneous hot fires that release carbon into the atmosphere rather than locking it within the soil.¹⁷

These successful farmers of the Americas offer lessons in soil management that have sustained their crop production for thousands of years. Using an intensive landscape-management scheme, they kept the forests healthy by frequent regeneration, built soil health and aggregation, and simultaneously produced a myriad of food types. This raises the question: Is it imaginable that swidden agriculture could be adopted more broadly? Could today's conventional and industrial farms integrate intensive management of gardens into a cropping strategy that maintains both soil health and satisfactory yields? These interventions may be too radical or difficult to scale up for widespread adoption, but we need to consider every proven practice for enhancing soil if we expect food production to continue at the scale needed to feed the growing global population.

As desertification expands the reaches of arid land, it is essential to learn how indigenous people have farmed drylands for centuries. The Zuni Pueblo Indians in the southwestern United States practice one of the oldest agricultural systems in North America, where they have farmed continuously and combated erosion for millennia.¹⁸ Linguists believe that the Zuni language, unique among Indian languages, may have been used in the same geographic area for seven thousand years. But without written records, language does not leave behind physical artifacts. Fortunately, farming does. Archaeologists have found evidence that the Zuni have farmed the same land continuously for three thousand to four thousand years, indicative of a society that protects its soil.

Zuni ancestors, known as *awu:wu:na:awe:kwi:kowa*, migrated from today's Central America and Mexico about four thousand years ago, bringing with them foods that remain staples of the Zuni diet today—maize, beans, and squash. These plants have provided the primary nutrition for centuries, including during a sharp population expansion that occurred sometime around 1200 CE. At first glance, it is remarkable that anything grows in the arid Zuni land, but despite its barren appearance, this desert is in one of the five most biodiverse regions of North America, supporting organisms that have navigated the challenges of desert life, as have the Zuni.¹⁹ Their farming practices use water judiciously and manage erosion in a climate of extremes.

Appropriation of land by European settlers and the U.S. government shrank Zuni territory from a sprawling 6 million hectares (almost the size of Ireland) to its current size of less than 200,000 hectares (smaller than the city of Johannesburg, South Africa). Despite facing both a harsh environment and invaders who stole the land that contains their heritage, the Zuni have maintained food produc-

tion using their own innovative farming practices and have protected their soil from devastating erosion.²⁰

Zuni lands are largely semiarid Aridisols with some extending onto Mollisols and Alfisols at higher, more humid elevations on the eastern edge of the region. The land is subject to prolonged droughts punctuated with torrential rains that wash away the fragile soil. Erosion is apparent in the arroyos—deep incisions in the land cut by rain. For unknown reasons, extant arroyos first cut the earth between 1880 and 1919 and continued to expand, some reaching 30 meters deep and 50 meters wide. The gushing water that gouges these deep canyons often arrives in a few torrential thunderstorms during July, August, and September.

Episodic access to water creates challenges for soil and crop management that the Zuni handle with runoff agriculture, an approach used throughout the world's arid lands, which involves collecting runoff water from upper, often forested, slopes during the wet season. The Zuni must use elevation to balance temperature and precipitation, inversely related variables, by strategically placing their fields above the valley floor but beneath a hillside that sheds water during torrential rains. The fields capture sediment and nutrients from the higher altitudes while avoiding the floods and frosts typical of the lowest points in the valley. To slow water movement, the Zuni construct small permeable dams of stone or brush that distribute the water and sediments. The dams act similarly to terraces, enabling the water to sink into the soil rather than flow over it. The brush is woven into networks that create a herringbone pattern, engineering channels that redirect water flow. The brush is particularly effective because of its hydraulic properties and semipermeable nature. Over time sediment and nutrients accumulate in the field, creating soil that is far deeper and richer than the surrounding land. To extract further benefit from the limited water supply, the Zuni have bred plant varieties

whose seeds can be planted 30 centimeters below the soil's hot surface, where water is available. Seedlings of these hearty plants must grow a long way to reach sunlight! Zuni breeding has also produced maize cultivars that, compared with cultivars in general use in the Southwest, carry more mycorrhizae, the root-infecting fungi that enhance root surface area. The Zuni plants are consequently more efficient at water and nutrient uptake.²¹

Agriculture and land managers have much to learn from the Zuni. They recognized long ago that the desert was not a wasteland, as many European settlers assumed, but instead a land of diversity. White settlers and the U.S. government arrived believing that they needed to teach the Zuni how to farm, but by the 1930s began to realize that the ingenious Zuni methods for water management were far more successful than anything introduced from outside the community for erosion control.²² By listening to the land, learning its cycles, and devising management practices to prevent soil movement and encourage its resilience, the Zuni have coaxed an abundance of food from the desert, nurturing the soil while nourishing themselves. Many farmers can draw on wise Zuni stewardship, and the philosophy underpinning it, to build soil legacies that will persist for centuries to come.

The Māori people of Aotearoa, or New Zealand, have protected soil through practices shaped by their deeply spiritual and cultural connections with the land. Their fight to preserve soil for centuries has placed them, like many indigenous peoples around the world, in conflict with European colonizers. The Māori endured seeing their land extensively deforested, degraded, and governed by a colonial ownership and management system. They have adapted to an imposed legal system in order to protect and rehabilitate the land using both traditional and conventional management styles, combining spirituality and science to navigate a system that is not their own.

They offer lessons in the power of human resilience in building—and rebuilding—land legacies.

Unlike the indigenous people of the Americas, who speak many languages across hundreds of nations that sprawl over a large continent, Māori share a common language and live mostly within New Zealand's two, relatively small, main islands. They arrived in New Zealand from Polynesia around 1350 CE and lived as hunter-gatherers before forming settlements surrounded by crops and horticulture. Their land management was based on knowledge and skills originating from Polynesia with a rich spiritual connection to the land and broader environment. In fact, Māori are known as *tangata whenua*, people of the land, illustrating their belief that humans do not own land but belong to the land and should give back to it what they take.²³ This mutually giving relationship is expressed through the common tradition of burying placentas to cement each child's bond with Papatūānuku, Mother Earth, and is linguistically embodied in the word *whenua*, which translates as both "placenta" and "land."

Today Māori rights and land guardianship remain precarious. Large tracts of land were lost mainly during the nineteenth century under a raft of colonial laws, and now Māori retain only 6 percent of their original traditional land area, despite filing hundreds of land claims and grievances. Their land is split into thousands of fragmented blocks, each with multiple landowners and a separate governance entity based on Māori land legislation passed in 1993. About 85 percent of Māori live in cities, leaving small rural communities to maintain the tribal homelands, or as they say, *ahi kaa*, which means "to keep the home fires burning." But both urban and rural Māori draw on traditional knowledge to develop new soil management practices that nourish their relationship to tribal areas and Māori land. Their spiritual and cultural connection with all living things impel the

Māori to become students of the soil, developing their own soil terms and classifications. They assess soil health largely through their senses, noting its color, smell, feel, and texture, and they use the term *mauri* to discuss the vitality of a soil and its ability to support diverse life-forms and to ensure well-being.

Confronting economic, social, and political forces that take and degrade the soil, Māori have sought to protect their traditions and beliefs about soil, especially their view of it as a living system that gives the people a sense of identity and unity.²⁴ Māori environmental researchers Jessica Hutchings, Garth Harmsworth, and colleagues have created a new framework for soil health based on Māori values of ancestral lineage, interconnectedness, and divinity. The framework reinforces Māori rights of sovereignty and guides them to fulfill their guardianship responsibilities for land to improve its *mana*, a word that has many layers of meaning, including power, honor, prestige, fertility, and health. Māori farming and cropping practices elevate a soil's mana by enriching its fertility, increasing microbial diversity with nitrogen-fixing plants, adding compost and other amendments, and avoiding chemical additives and mechanical degradation.

In the nineteenth century, British settlers sought to profit from New Zealand's natural resources and brought a starkly contrasting, nonspiritual view of soil, land, and ownership to New Zealand. Despite much resistance by Māori, the British convinced hundreds of chiefs to sign the Treaty of Waitangi in 1840, a document that was interpreted very differently by the Māori and British and remains the subject of ongoing debate. The treaty abruptly resulted in colonial appropriation of more than one million hectares of land and infrastructural projects that scarred Māori landscapes with deforestation, sprawling pastoral agriculture, roads, drainage systems, and British settlements.

To a large extent, Māori have now accepted the treaty as a constitutional basis of Aotearoa–New Zealand, with the Māori version of the treaty providing a high level of indigenous rights and participation. New treaty legislation has also helped to elevate rights for Māori in tribal areas and across New Zealand, supporting them to take a more prominent role in decision-making over national natural resources. Internationally, this model of co-management and co-governance drew attention when Māori concepts infiltrated mainstream legislation and policy with historic legislation in 2014 and 2017 that awarded personhood to a tract of conservation land and a river.²⁵ Many Māori hope that soil will be next to gain the recognition of personhood.

New Zealand's Waipua catchment in the eastern North Island is an area of steep hills covered in fragile soil. It is the spiritual and cultural home of the Ngāti Porou tribe. After thousands of years of stability under native forest, the catchment is now among the worst erosion sites in the world with very high sedimentation in the rivers and streams. While under the native forest canopy and leaf litter, the soil was protected from the high intensity rainstorms and tropical cyclones that frequent the area. Traditional Māori agriculture and natural forest management had also enriched the soil with a compost made of shells, seaweed, and discarded plant material. After colonization, deforestation, and a transition to pastoralism, the catchment became highly degraded and lost thousands of tonnes of soil. Without its protective covering, the sloped land became pocked with deep gullies, and sediments slid into the Waipua, a river of profound spiritual significance to the Māori. Today soil erodes at a staggering 180 tonnes per hectare per year, muddying the sacred river, raising its bottom by 2.4 meters per year, and damaging local floodplains and Māori farms (see pl. 3).²⁶

Like so many other places in the world, New Zealand today is

experiencing the effects of climate change in more frequent, heavy rainstorms that pummel the land with high-velocity raindrops, driving soil off hillslopes at an alarming rate. What's more, almost 60 percent of New Zealand is classified as mountainous, hilly, and vulnerable to hill-country erosion. Reforestation efforts across New Zealand focus on creating a naturally diverse forest that will protect, rebuild, and anchor soil in place. Māori have been at the forefront of these soil conservation and land development initiatives. One tree species that has attracted special interest because of its cultural and economic value to Māori is the mānuka (*Leptospermum scoparium*), which is native to New Zealand and provides nectar for pollinating western honey bees. Mānuka trees are also very important to soil conservation in the east coast region that includes the Waipua catchment. The bees themselves have a remarkable history, having been imported in the late nineteenth century by a British beekeeper, Mary Bunby, who kept them alive for the six-month voyage from England to New Zealand. She made the first honey on the island, probably feeding the honey bees on mānuka nectar, a practice that has since expanded. Māori medicine (*rongoā*) employs the honey for healing, and in the twenty-first century mānuka honey reached Western shores, where it has taken hold, touted by biochemists, health commentators, and actors for its antibacterial and wound-healing properties.²⁷ Today the bees are helping reforest and protect Māori land, reducing erosion, and increasing the income of the indigenous community. The mānuka tree may be the most famous and lucrative example, but farmers and foresters have introduced other species into the Waipua catchment to protect the soil and restore the once lush ecosystem.

Planting trees to restore the landscape is an effective strategy to protect and build soil, and in many locations, it is the best way to do so. Tree roots are terrific soil managers, binding soil particles, feeding microorganisms, and recruiting nutrients from deep in the soil profile

to the top horizons. New Zealand's government aims to plant trees throughout eroded areas, but misguided policies have alienated many Māori. The government's Emissions Trading Scheme, for instance, provides incentives for reducing atmospheric carbon by planting exotic trees such as pines, whereas Māori yearn to restore native forests from their *whakapapa* (ancestral lineage) with the diversity that builds soil mana and supports the ecosystem. In the nineteenth century the Europeans defiled Māori land by replacing forests with pastures; today the government repeats that insult by designing solutions that disregard Māori spirituality, traditional practices, and knowledge of the land. Although individuals are no doubt attempting to bridge the gulf, the government as a whole stands in stark contrast with Māori philosophy and land practices.

Māori are beginning to take a stronger role in developing New Zealand's land restoration policy, applying their knowledge of wise stewardship. They hope to partner with the national government, local government agencies, industries, and a range of other stakeholders to reclaim their rights and the ground of their cultural heritage. The rest of the world can draw inspiration from the Māori's spiritual and cultural attitude toward land. Their partnership with the soil—indeed, their belief that they are *of* the soil—taught them to be talented land stewards. Even cultures lacking such a spiritual link with the soil can learn from the outcomes of that spirituality.

As we study the underground ribbon that connects the past and future, what can we learn from indigenous soil legacies? First, plant diversity is a striking feature common to several, such as the Maya milpa gardens, Zuni runoff agriculture, and Māori forests. Each system capitalizes on many local species to nourish and anchor the soil and support a robust ecosystem. Plant diversity is the antithesis of con-

ventional modern agriculture in which monocropping rules the field, weeds are eradicated, and, depending on commodity prices and bio-fuel markets, farmers may plant the same crop for several consecutive years. The second commonality is water management. The Maya and Ifugaos use terraces, and the Zuni build dams to reduce the velocity of water and to redirect it. The Māori depend on trees to intercept raindrops, reducing their impact on soil aggregates when they land. The third theme is the application of organic amendments to the soil. In Papa Stour, the farmers enriched the soil with manure, turf, and seaweed, producing plaggen soil. The Maya and Amazonians used weeds and other plant waste, the Māori use seashells, fire ash, and seaweeds, and the chinampas are stuffed with peat. All of these practices produce black soils that are richer than the surrounding earth in nonagricultural sites. And finally, none of these land stewards plow their fields. All have minimal impact on their soils through the use of sticks, spades, or hand planting, enabling the soil to build robust structure. The lessons are reinforced by the failures. When the Maya ceased the twenty-year soil regeneration cycle, their milpa system struggled. When the European immigrants deforested Māori land, New Zealand developed some of the worst erosion sites in the world.

History is full of agricultural systems that have failed and disappeared, often along with the societies that depended upon them for sustenance. Others persist after centuries or millennia of continuous practice, stitching the ribbon that links the past and future. Soil that is nurtured and protected grows deep and dark, leaving an inheritance of both soil and the blueprint to make more of it. Most agricultural practices are on track to deplete much of the Earth's soil in a few short decades. Looking at the cultures that have sustained their soil throughout most of agrarian history, we should be appalled at the current trajectory of conventional agriculture. We can do so much

better. The principles are well known, and the practices are adaptable. The burden of protecting soil cannot be relegated to indigenous people and environmental activists. All of us who depend on mainstream agricultural production need to demand wholesale change in management if we plan to continue to eat.

Soil Heroes



When I was a child, one of my favorite picture books was about a farm. Its illustrations depicting rolling hills verdant with crops and dotted with cows, a farmer on his red tractor, and a girl carrying pails of fresh milk from the barn to a tidy white house surrounded by colorful flowers portrayed a life of bucolic bliss. A life that looked peaceful, enduring, and safe. Modern agriculture across the world is quite distant from this romanticized image. It's a demanding life full of tough choices and uncertainty. Many people farm to produce food for their own families. Others inherit land with generations of toil and history buried in it and feel obligated to continue farming. And