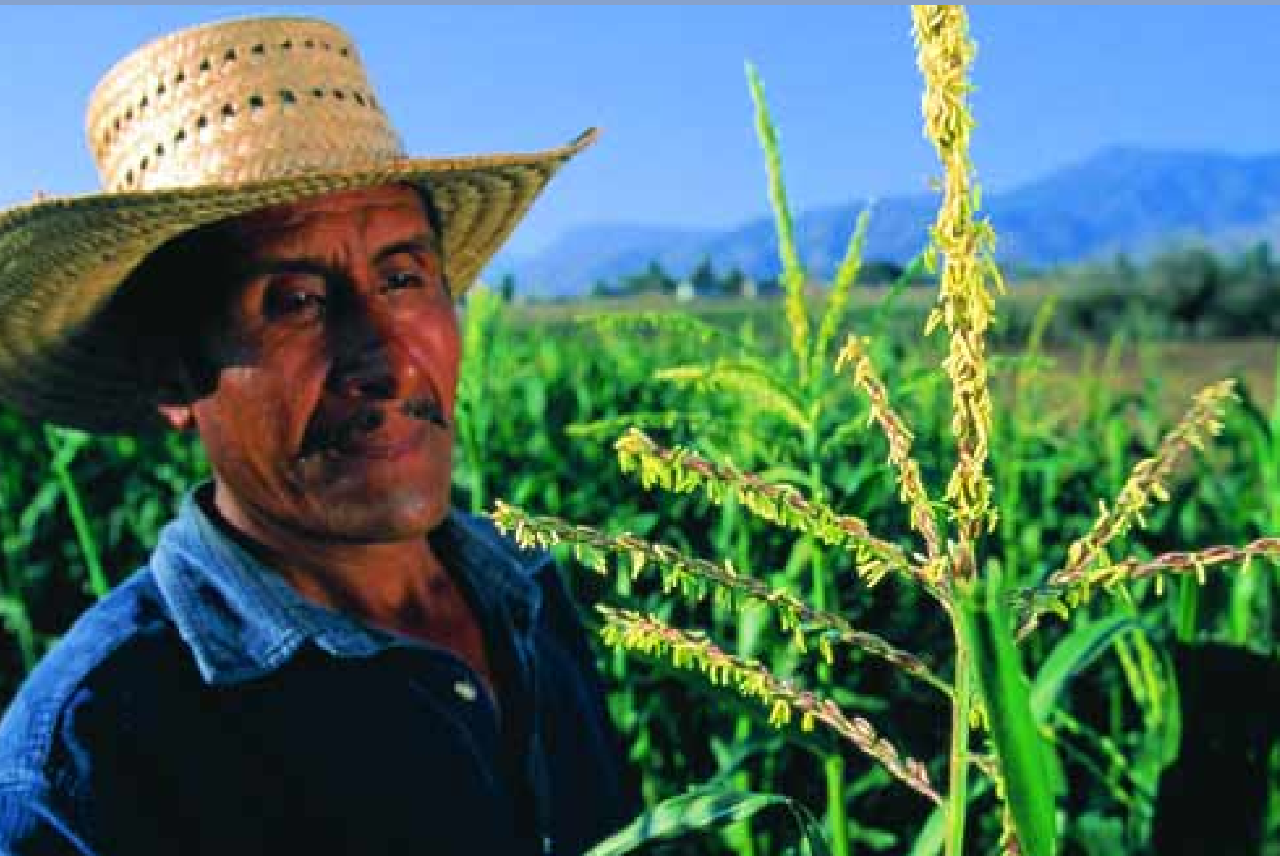
Diversity on the Farm

How traditional crops around the world help to feed us all, and why we should reward the people who grow them.



By Charles C. Mann

FORD FOUNDATION

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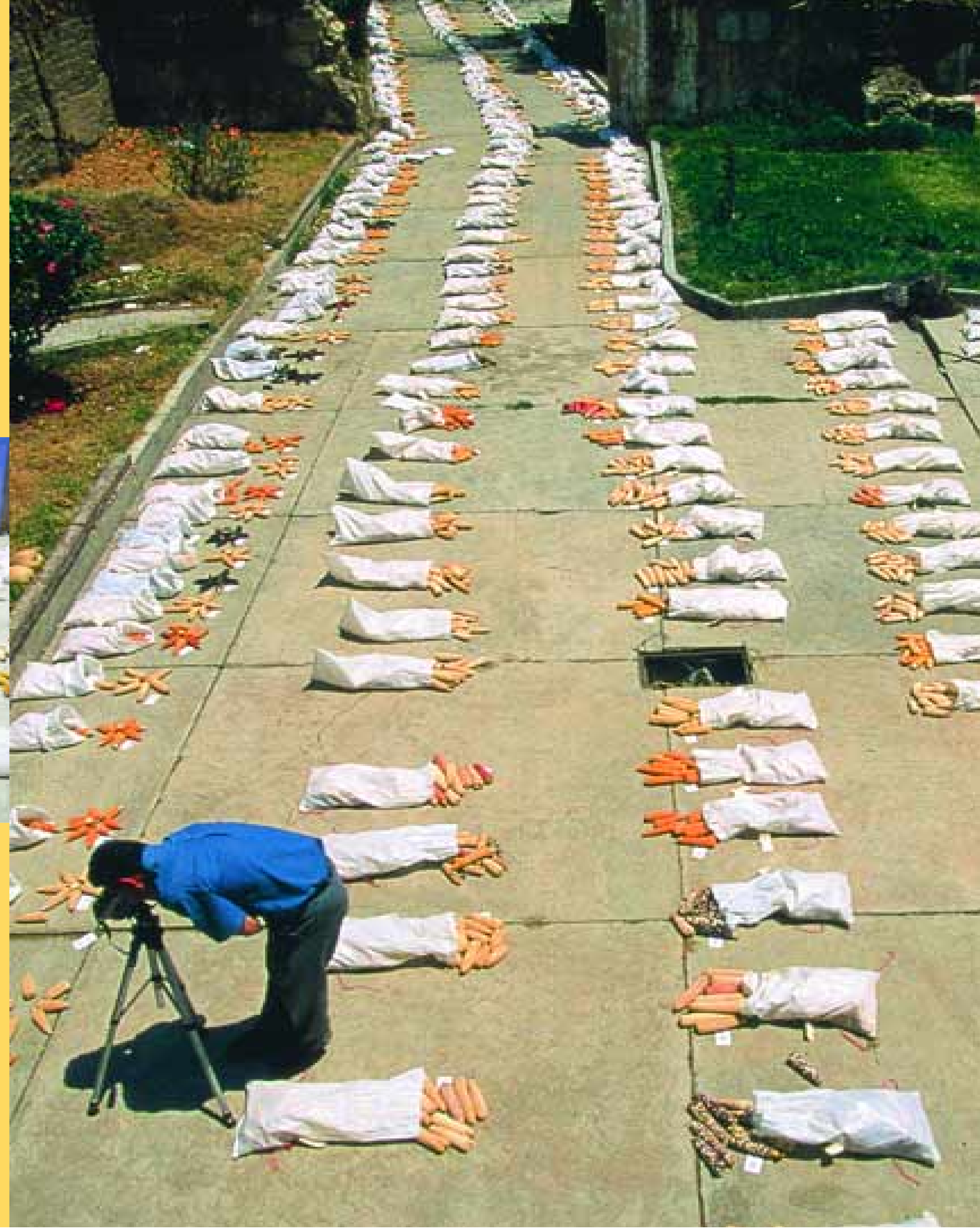
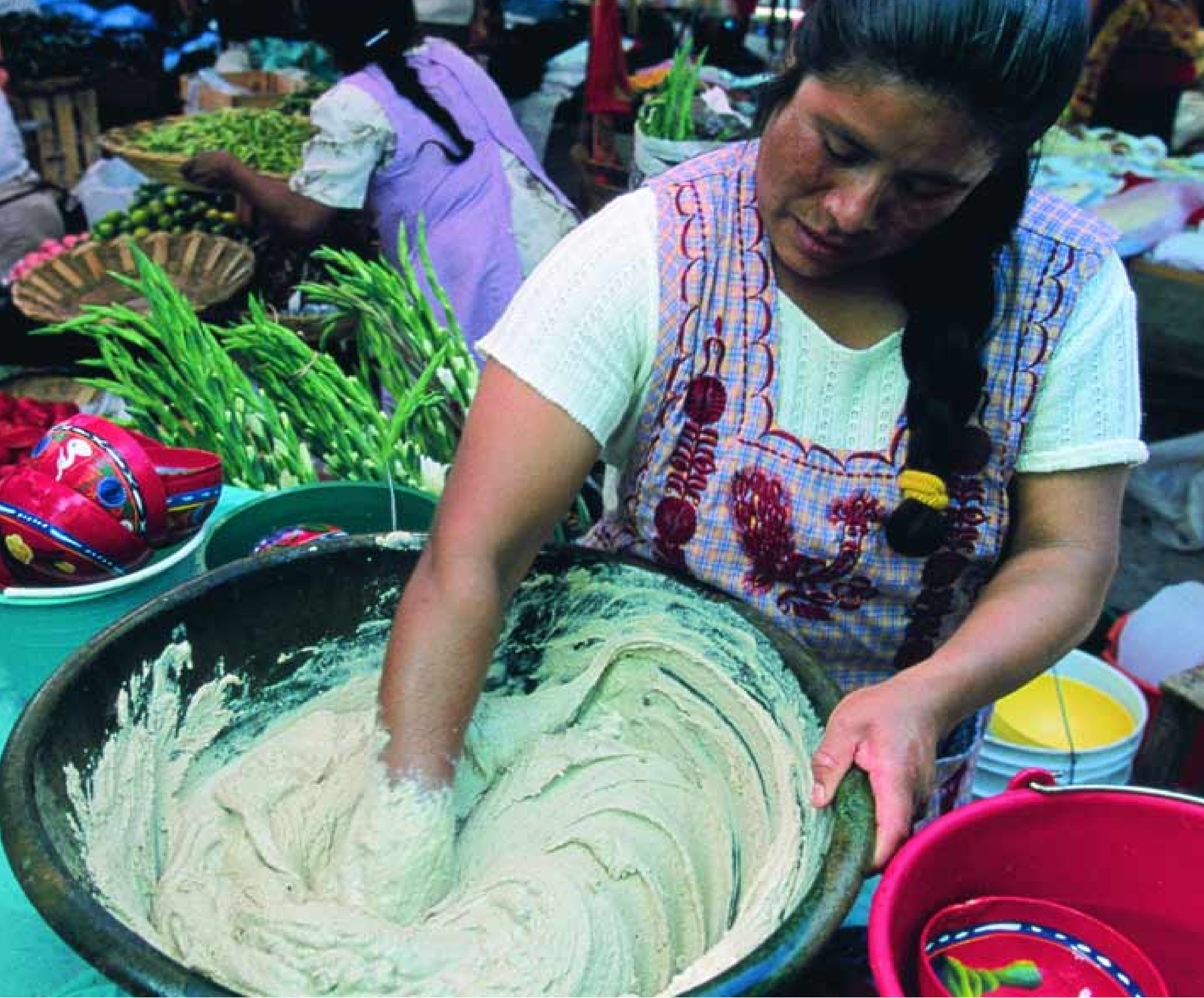
Maize

Front cover, left: Hector Diaz Castellano, a Zapotec small-holder, on his farm in the hills of southern Mexico; right: an array of native maize varieties.



Above and right: Post-harvest survey of native maize varieties at INIFAP, an agricultural-research institute outside the city of Oaxaca; inside left: making the maize drink *atole* in a country market; inside right: rinsing off the lime used to process maize kernels for hand-made tortillas in Ítanoni, an unusual gourmet tortillería in Oaxaca city that may serve as one model for saving agricultural biodiversity.



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Photographs by Peter Menzel

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At Ítanoni, hand-made tortillas from single varieties of native maize are cooked on traditional circular clay griddles called *comales.*

2 Mission Statements

3 Foreword

5 Introduction

7 Building the Roof with Stones from the Foundation

11 Conserving Agricultural Biodiversity

13 A Community Effort

17 From the Stomach to the Heart

19 What We Can Do: Five Approaches
1. Labeling
2. Crop improvement
3. Removing perverse incentives
4. Paying for currently uncompensated services
5. Increasing social capital

23 The Best Tortillas in Mexico

25 Notes

28 Credits

FORD FOUNDATION

The Ford Foundation is a resource for innovative people and institutions worldwide.

Our goals are to:
- Strengthen democratic values,
- Reduce poverty and injustice,
- Promote international cooperation, and
- Advance human achievement.

This has been our purpose for more than half a century.

A fundamental challenge facing every society is to create political, economic, and social systems that promote peace, human welfare, and the sustainability of the environment on which life depends. We believe that the best way to meet this challenge is to encourage initiatives by those living and working closest to where problems are located; to promote collaboration among the nonprofit, government, and business sectors; and to ensure participation by men and women from diverse communities and at all levels of society. In our experience, such activities help build common understanding, enhance excellence, enable people to improve their lives, and reinforce their commitment to society.

Asset Building and Community Development Program

The Foundation's Asset Building and Community Development Program supports efforts to reduce poverty and injustice by helping to build the financial, natural, social, and human assets of low-income individuals and communities.

Environment and Development Affinity Group (EDAG)

The Environment and Development Affinity Group is an association of Ford Foundation program staff whose mission is to promote global learning and mobilize change in the field of environment and development. It promotes a theory and practice of development worldwide that is compatible with the sustainable and equitable use of environmental assets, including the protection, restoration, and enhancement of environmental quality, and respect for diverse cultural values and vitality. Members of the EDAG support research, convening, peer learning, advocacy, and networking to improve the effectiveness of the Foundation's grantmaking in the environment and development field.

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The Political Economy Research Institute (PERI) was founded at the University of Massachusetts, Amherst, in 1998. PERI's mission is to facilitate research, graduate education, and outreach in the area of policy-relevant political economy. The Institute is committed to conducting and disseminating research to inform policy makers and grassroots activists who are trying to improve living standards and to create a more just, democratic, and ecologically sustainable world.

Natural Assets Project

The Natural Assets Project is a collaborative initiative that aims to promote critical analysis and discussion of the potential for building natural assets – individual and social wealth based on natural resources and ecosystem services – to advance the goals of poverty reduction, environmental protection, and environmental justice.

Foreword By Deborah Barry

What does "genetic erosion" mean for agriculture, and how does it relate to small farmer production of corn in Latin America? How does the fate of a small farmer's struggle against poverty on the hillsides of Chiapas affect the future of agrobiodiversity or the fight against future famine? Could an increase in the production of 'real Mexican' tortillas help maintain one of the most important cultural and biological assets in the world? And just why does this constitute a concern of global importance?

These are some of the critical issues addressed by Charles Mann in this skillfully constructed analysis of the intimate relationship between the knowledge of peasants who have produced corn for thousands of years, the impact of biotechnology on agriculture, and the future of food supply for many of the earth's inhabitants. Mann draws on his understanding of the cultural richness surrounding corn production and usage in Mexico, and the impacts of applied modern science and market liberalization to outline the threats to biodiversity and describe some initial steps that can be taken to alleviate the consequences.

Why is the work mentioned in this article of special importance to the Ford Foundation? How does it reveal the logic underlying Ford´s philanthropic support in this field? Why undertake this analysis at this point? What importance could it have for other funders and development organizations? Those questions provide the focus of this brief foreword.

For the past five years, the Ford Foundation's work on the reduction of poverty and injustice has been organized conceptually under an approach that promotes community action for the building of assets. The asset-building approach to poverty alleviation provides a significant departure from other paradigms that focused primarily upon subsidy and transfer programs that temporarily raise the incomes or consumption levels of persons deemed to be poor, without affecting significantly the determinants of that poverty (cf. Sherraden 1991; Oliver and Shapiro 1995; and Ford Foundation 2002). The asset-building approach centers on building the enduring resources – indeed, the assets – that individuals, organizations, or communities can acquire, develop, improve and transfer across generations. These assets include (2002, pp. 2-3):

• Human assets such as education and other marketable skills that allow low-income people to obtain and retain employment that pays a living wage.

• Financial holdings of low-income people, such as savings, homeownership, and equity in a business;

• Social bonds and community relations that constitute the social capital and civic culture of a place and that can break down the isolation of the poor, as well as the networks of interpersonal and intergenerational relationships that individuals need as a base of security and support; and

• Natural resources, such as forests, plants, wildlife, land, and livestock that can provide communities with sustainable livelihoods, as well as environmental services such as a forest's role in the cleansing, recycling, and renewal of the air and water that sustain human life.

When this approach is applied to communities that depend upon converting natural resources into sustainable livelihoods, it becomes a strategy for building the natural assets of these communities. The theoretical bases for building natural assets have been explored by Boyce (2001), Boyce and Pastor (2001), and Boyce and Shelley (2003). Boyce and his co-authors note that the application of asset-building strategies to natural assets is compelling because "strategies for building natural assets in the hands of low-income individuals and communities can simultaneously advance the goals of poverty reduction, environmental protection and environmental justice" (2001, p. 268). This countermands the conventional wisdom that the poor face an inescapable trade-off between higher incomes and a better environment. And building natural assets can contribute not only increased income but also nonincome benefits such as health and environmental quality.

For more than 20 years, Ford Foundation programs around the world have sought to develop mechanisms under which poor local communities can take their futures into their own hands, and in this case, build their livelihoods upon the contributions they make to the larger "global" community. Support for efforts to understand the intricate relationship between human culture, agricultural production under conditions of poverty, and the genetic evolution of corn or Mexican maize forms part of the Foundation's environment and development work in Mexico. How to ensure the ongoing *in-situ* cultivation of genetically diverse corn by the protagonists of this evolutionary process – the campesino farmers in the highlands of Mexico – constitutes the next stage of this challenge.

Mann argues that what is needed is the perpetuation of this "living laboratory" for the preservation and evolution of the species found in the smallholder production of corn in the centers of origin in Mexico. His illustration of the dilemmas of genetic erosion of maize in Mexico contributes to our understanding of the threats to other agricultural products around the world.

The article ends with a suggestion for five approaches to help thwart this trend. Mann sketches proposals which range from developing a more creative use of labeling products developed from specific varieties, to the promotion of policies and mechanisms that recognize that smallholders who maintain agricultural biodiversity are providing genetic insurance for the rest of the world and should be compensated for it. This piece recognizes the global environmental services being provided by some of the poorest farmers in the world and sets the stage for exploring how to provide just compensation. These and other recommendations provide insightful and ultimately optimistic bases for rethinking and restructuring our most basic concepts about community-based building of natural assets in the face of contemporary global challenges.

Deborah Barry
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Diversity on the Farm

By Charles C. Mann

Just after dawn the metal grating rolls up at a small shop in a middle-class neighborhood of the city of Oaxaca, in southern Mexico. Inside the front room, half a dozen women hover over *comales*—waist-high, dome-like stoves made of concrete block and clay. Recessed into the top of each *comal* are two concave clay dishes that serve as burners, the larger of the two splashed with the bright dry white of lime. A few minutes after the store opens, the burners are hot enough to use. With expert motions the women slip tortillas—thin discs of cream-colored flour perhaps nine inches in diameter—onto the hot surface of the burners. Almost instantly the tortillas dry and puff up like soufflés. And from the storefront floats the aroma of toasting maize, a smell that has characterized the villages of Mexico and Central America for thousands of years.[1]

Gourmet tortilleria owners Amado Ramírez Leyva and his wife, Lea Gabriela.

This small store is the site of a big experiment. Established by Amado Ramírez Leyva, a Oaxaca native, it is an innovative attempt to preserve one of Earth's greatest—and most threatened—cultural and biological assets: the many local varieties of maize in southern Mexico. With the adjacent states of Chiapas and Guerrero, Oaxaca is the "center of diversity" for the species: the place where Indian farmers developed modern maize from its wild relatives thousands of years ago. In terms of annual production, maize today is the world's single most important crop, a staple for hundreds of millions of people in the Americas, Africa, and Europe.[2] But in recent decades neither the original strains of maize nor the descendants of the Indians who developed them have fared well. An unhappy pile-up of circumstances—globalization of markets, economic polices that work against small landholders, social neglect—has made it so difficult for rural farmers to survive that many are leaving their villages for good. Others are trying to make a go of it with contemporary hybrids. As a result, traditional varieties are at risk of disappearing. In the form of tortillas and other foods, this type of local maize has long been an essential element of Mesoamerican society; its disappearance is a blow to the culture. More important, because the many strains of farmer maize are storehouses of valuable traits for modern plant breeders, the loss of traditional varieties is a long-term threat to the global food supply. The tortilla store is Ramírez Leyva's attempt to do something about it.

Genetic Erosion: A Threat to Food Security

Tortillas are to Mexico what flaky-crusted bread is to France or short-grained rice is to Japan: a food that is an emblem of home.[3] Thirty years ago, hand-made tortillas from local maize were served at almost every Mexican dinner table. Today, bizarre though it sounds, it has become almost impossible to get a good tortilla in Mexico, even in culinary centers like Mexico City.[4] In gastronomic terms, it's as if all the craft-baked bread in France had been replaced by packaged white bread. Most maize now on Mexican shelves is a mix of industrial hybrid and modern varieties, many of them genetically modified, from large Mexican and U.S. producers. Alas, this melange lacks the qualities necessary to make a good tortilla. Nor can industrial maize make proper *niquatole*, *tejate*, *atole*, or any of the other traditional maize-based foods in Mexican cuisine.

Ramírez Leyva began traveling throughout Oaxaca in 2000 to set up a network of traditional farmers, most of them Indians. The farmers now supply eight different maize varieties to his shop, Itanoní, where the kernels are carefully ground, hand-formed into tortillas, and cooked fresh for customers. (The name Itanoní means "maize flower," in Mixtec, a local Indian language; as one might imagine, it refers to a flower that blooms in country maize fields.) Itanoní is one of the few tortillerías in Mexico—indeed, perhaps the *only* tortillería in Mexico—that sells what might be described as "estate" tortillas: tortillas that are proudly labeled as being made from maize of one variety, from one area.[5] Building on the profits from the first store, Ramírez Leyva intends to open others across Mexico. The ultimate hope is to create a chain of franchises, though each Itanoní, unlike typical franchise stores, will be different, selling products only from its own locality. If the enterprise works out, he will expand to the United States, first targeting immigrants from Oaxaca, then moving to the rest of the population. Ultimately, middle-class money from all over North America will flow back to the Oaxaqueño countryside, simultaneously helping to preserve traditional Mexican cuisine, assisting some of Mexico's poorest farmers, and protecting the world's stock of diversity.

Itanoní just opened its doors in 2001, so it is too early to gauge whether the store will succeed, let alone whether Ramírez Leyva can use it as the base of a national chain. Nonetheless, this tiny shop in this mid-sized town has drawn considerable attention, because crops around the world, like maize in Mexico, are threatened with "genetic erosion"—the loss of the traditional varieties and wild relatives of today's food crops. More than 80 percent of the world's annual tonnage of agricultural crops is accounted for by just 12 species: the cereals wheat, maize, rice, barley, and sorghum; the tubers potato, manioc, and sweet potato; the sugar sources sugar cane and sugar beet; the fruit banana; and the pulse (as agronomists call beans and other legume seeds) soybean.[6] All were domesticated from wild relatives thousands of years ago. And all are threatened by genetic erosion. Humankind cultivates another 200-odd crops—fruits, nuts, and vegetables, for the most part. Many if not most of these are losing traditional varieties and wild relatives, too.[7]

The threats to complex biological systems are always difficult to quantify, but the stakes are clearly high. Each of the major food crops is vital to the lives and cultures of millions of people—billions, in the case of cereals. Because a crop's traditional varieties and wild relatives usually contain most of its gene pool, they are the raw genetic material out of which plant breeders develop new varieties. Understanding their dependence on agricultural biodiversity— the genetic variation in crops—plant breeders have long worried about its loss. The worries proved prophetic when southern corn-leaf blight, caused by a mutant version of the fungus *Bipolaris maydis*, erupted across most of the U.S. Southeast in the early 1970s, destroying a billion bushels of maize, including much of the seed for the next year's crop.[8] Providentially, scientists were quickly able to breed resistant strains, and then found more long-lasting resistance in varieties of maize in Africa. But they were shaken by how close the system had come to disaster—they had been lucky that the problem was quickly contained, and luckier still that the African maize had not been supplanted by vulnerable modern hybrids.

Since the corn-leaf blight disaster, countries around the world have built up large collections of seed—gene banks or germplasm banks, as they are sometimes called. But at the same time it is widely recognized that collections are not enough, in somewhat the way that preserving endangered animals in zoos is not equivalent to preserving them in the wild. *Ex-situ* conservation—protecting seed samples in repositories—cannot capture the dynamism of *in-situ* systems. The farmers who now work with traditional varieties have detailed, practical knowledge of their traits. If in the future these varieties exist only as samples in gene banks, the world will have lost this expertise, and plant breeders will be hard pressed actually to use the diversity they have saved.

"It seems incredible, but maize production throughout the world may depend on the small farmers in southern Mexico," says Maurice Bellon, a maize researcher at the International Maize and Wheat Improvement Center (known as CIMMYT, after its Spanish acronym), outside Mexico City. "And this is also true of farmers in the centers of origin of other crops. So we have to find a way to keep these farmers in their fields, despite all the circumstances against them. Unfortunately, it is not at all clear how to do that."[9]

Which, just possibly, is where Ramírez Leyva and Itanoní come in.

Building the Roof with Stones from the Foundation

In 1975, Amado Ramírez Leyva left his home village in Oaxaca to study at the University of Chapingo, outside Mexico City. He was just 15. After picking up a degree in agricultural economics at Chapingo, he won a UNESCO fellowship to Germany. He earned a master's degree from Berlin's Humboldt University in 1987. One of the most important lessons Europe taught Ramírez Leyva was the depth of his bond with his native soil. "I read [the great Mexican writer] Juan Rulfo for the first time in Berlin," he says. "It was like all my pores opened up and my whole body was suffused with the feeling of my home." He returned to teach at the University of Chapingo, wanting to help his country but not sure how to go about it.

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Ramírez Leyva took a leave in 1990 to work as a consultant in Chiapas, Mexico's southernmost state, one of the poorest areas in the country. Wanting to learn how people's lives could be improved without destroying their culture, he stayed in impoverished villages for extended periods—at one point he lived for two months in the jungle on just ten pesos. Two years later, he left the university for good. With his wife, Lea Gabriela, whom he had met in Chiapas, he returned to Oaxaca in the hope of putting his inchoate ideas into action—"a crazy move," he says, "for a crazy place."

Pinched between the Gulf of Mexico and the Pacific Ocean, Oaxaca is a jumble of mountains, beaches, wet tropical forests, and dry savannas. Along with neighboring Chiapas and Guerrero, it is the most diverse area, ecologically speaking, in Mesoamerica. "Some parts of Oaxaca go up 9,000 feet," says T. Boone Hallberg, a botanist at the Oaxaca Institute of Technology. "Sometimes the soil is very acid, sometimes it's quite basic—all within a few hundred feet. You can go on either side of a highway, and the climate will be different on the east side than on the west side."[10] The area's human geography is equally diverse: it is the home of 16 Indian groups, almost all of whom have lived there for millennia. Prominent among them is the Zapotec, whose ancestors founded Monte Albán, probably the Americas' first large city, some 2,500 years ago. At its peak in the first few centuries A.D., Monte Albán covered seven square kilometers and may have had 20,000 inhabitants, making it larger at the time than any city in Europe. The peoples of southern Mexico were also those who created modern maize—a feat so improbable and difficult that archaeologists and biologists have argued for decades over how it was achieved.[11]

The refrigerated, earthquake-resistant maize and wheat seed bank at the International Maize and Wheat Improvement Center, outside Mexico City.

To top off the accomplishment, maize became the center of an innovative agricultural system called the *milpa*. The term comes from the Aztec term for "maize field," but a *milpa* itself is considerably more complex: it is a field, usually but not always recently cleared, in which maize, beans, squash, and other crops are grown at the same time. The diversity makes the *milpa* look untidy, but it has important ecological implications. Typical single-crop regimes, much less diverse than natural ecosystems, tend over time to exhaust the soil. In Europe and Asia, farmers try to avoid these difficulties by crop rotation; they plant wheat one year, for example, legumes the next, and let the field lie fallow in the year following. In a *milpa*, by contrast, pre-Hispanic peoples planted a dozen or more crops simultaneously: multiple varieties of squash, bean, melon, tomatoes, chilis, sweet potato, jicama (a tuber), amaranth (a grain-like plant), and mucuna (a tropical legume), among them.[12] "There are places in Mesoamerica that have been continuously cultivated for four thousand years and are still productive," says H. Garrison Wilkes, a maize researcher at the University of Massachusetts in Boston. "The *milpa* is the only system that would permit that kind of long-term use."

Maize and beans are agriculturally and nutritionally complementary. In the field, tall maize plants create a ladder for bean runners to climb; below ground, the beans' nitrogen-fixing roots provide nutrients needed by maize plants. As a food, maize lacks the essential amino acids lysine and tryptophan, which the human body needs to make proteins and niacin; diets with too much maize can lead to protein deficiency and pellagra (a disease caused by lack of niacin). Beans have both lysine and tryptophan, but lack the amino acids cysteine and methionine, which are provided by maize. As a result, beans and maize make a nutritionally complete meal; supplemented by avocado, the highest-calorie fruit, the meal is also incredibly filling. "The *milpa* is one of the most successful human inventions ever created," Wilkes says. "Mesoamerica—southern Mexico and Guatemala—still has much to teach us."

In agronomists' jargon, Mesoamerica is a "Vavilov center"[13]—one of the seven places on Earth where agriculture originated, according to the great Russian botanist Nikolai I. Vavilov. In the 1920s and 1930s Vavilov took part in more than a hundred expeditions to collect crop varieties, including two trips to Mexico in 1930 and 1932. During his travels, he discovered that agricultural biodiversity was not spread evenly around the world. Rather, it was concentrated in a handful of hot spots, which later became known as Vavilov centers. In addition to southern Mexico, the Vavilov centers are southwest Asia (Near East), tropical south Asia (India), east Asia (China); the Mediterranean shoreline; Ethiopia; and the Andes. Each is the center of diversity for many crops; the Fertile Crescent, for example, is the center of diversity for wheat, barley, rye, chickpeas, lentils, peas, figs, muskmelon, and flax.[14] Later scientists disputed Vavilov's tally of centers as too large, too small, or too simplified, with doubts focusing especially on the inclusion of the Mediterranean.[15] But no one doubts that agricultural diversity is centered in a few areas, almost all of them in the Third World. (Vavilov himself did not live long to enjoy his achievements; he was imprisoned by Stalin and died in a prison camp in 1943.)

Today the Vavilov centers are more important than ever before, because agriculture has increasingly centered on the high-yield varieties created in the wake of the Green Revolution of the 1960s and 1970s. The Green Revolution—a potent combination of higher-yielding

In the field, tall maize plants create a ladder for bean runners to climb; below ground, the beans' nitrogen-fixing roots provide nutrients needed by maize plants.

grain varieties, greatly increased use of chemical fertilizers, and the techniques to demonstrate their use to poor farmers—helped much of Asia and Latin America to achieve agricultural self-sufficiency, despite rapidly growing populations. In the mid-1960s, according to the United Nations Food and Agricultural Organization, 56 percent of the human race lived in nations with average per-capita food supplies of 2,200 kilocalories per day or less, a level barely enough to get by. As human numbers climbed relentlessly, population seemed destined to outstrip food production in the classic Malthusian scenario. Instead, grain harvests soared. Average rice yields in South and Southeast Asia, for example, rose by more than 80 percent from the mid-1960s to the mid-1990s.[16] Meanwhile, typical U.S. maize yields more than doubled. They now hover around ten tons per hectare, with some farmers getting 20 tons per hectare. As a result, FAO estimates, the percentage of the world's population living in countries at or below 2,200 kilocalories per day had fallen to ten percent by the mid-1990s. Without the explosion in supply from the adoption of high-yielding varieties, a research team led by Yale economists Robert Evenson and Douglas Gollin calculated in 2003, grain prices in developing countries would be 35 to 66 percent higher than they are today. In those places, the team argued, the lower price translates into saving

32 to 42 million preschool children from malnourishment and "considerably" lower infant and child mortality overall—an achievement by any standard.[17]

But the Green Revolution had an ecological downside, the loss of agricultural diversity prominent in it.[18] Traditional varieties, outperformed by Green Revolution hybrids, were rapidly supplanted throughout the world. No comprehensive surveys of the losses exist, but many examples suggest its scope. Some 2,000 types of rice grew in Sri Lanka in 1959, for example; 40 years later, the crop was dominated by just five.[19] Equivalent losses took place in Bangladesh, where almost two-thirds of the rice grown today is based on a single stock, and in Indonesia, where the figure is closer to three-quarters.[20] Worldwide, according to a 1990 study by Major M. Goodman, a maize geneticist at North Carolina State University, all commercial hybrids derive from six parental races. In the United States, the world's biggest maize grower, all commercial maize is descended, Goodman ascertained, from "only one race."[21] Large swathes of the Midwest are effectively devoted to monoculture, with single varieties of maize covering hundreds or thousands of contiguous acres. The number of rice varieties in China, the world's most important producer of that crop, is shrinking as well. Almost the entire Chinese rice crop is based on a few modern hybrids.[22]

Genetic erosion is not restricted to cereals. In the rush to adopt better-yielding breeds of vegetable, for example, more than three-quarters of Europe's traditional varieties have vanished. Vegetables have fared even more poorly in the United States, according to Cary Fowler and Pat Mooney, whose book *Shattering* (1990) was among the first to decry genetic erosion.[23] More than nine out of ten of the varieties in the official U.S. Department of Agriculture list in 1903, they say, were no longer available 80 years later. (New hybrids have been introduced, but they do not compensate for the losses.) As far back as 1972, the National Academy of Sciences reported that three-quarters of the U.S. potato crop comprised just three varieties.[24] The situation has not changed greatly since then.[25] "We built our roof with stones from our foundation," Fowler and Mooney remarked.[26]

Notoriously, the homogenization of crop varieties increases the vulnerability to pests: viruses, insects, bacteria, fungi. When many varieties of a crop are in fields, no single type of pest is likely to be able to attack them all—the varying genetic makeups provide a range of defenses wide enough as a rule to ensure that some will shake off the attack. Monocultures are much more vulnerable: the only pests that survive are those that can attack them. Following inexorable evolutionary processes, pest types for which the crop has no defense end up replacing other types, and selection pressures push them all to tailor themselves ever more exactly to the crop. To keep up with rapidly evolving disease and insects, breeders must continually develop new, resistant varieties; on average, a commercial maize variety can be used for just seven years.[27] The genetic material to develop new varieties is often found in the shrinking areas devoted to traditional crops.[28]

Examples are legion. Many of the virus-resistance genes in today's corn hybrids, for instance, come from *Zea diploperennis*, a wild maize relative that researchers discovered only in 1979, in the high Sierra de Manantlán, in the Mexican state of Jalisco.[29] The species also provides resistance genes to maize for witchweed, a parasitic plant that is a devastating problem for African maize farmers.[30] The entire species occupied fewer than 900 acres of land and could easily have been ploughed under before breeders learned about it. From its origin in the Caucasus, the Russian wheat aphid *Diuraphis noxia* spread throughout the western United States, much of Africa, and parts of Latin America; between 1987 and 1993, it cost an estimated $890 million in lost production, control expenses, and other losses in the U.S. alone.

Researchers found genes that conferred aphid resistance in little-known wheat varieties grown near the Iran-Turkmenistan border.[31]

Especially illustrative is rice-leaf bacteria blight, a disease caused by the bacteria *Xanthomonas oryzae pv. oryzae* (known as Xoo for short). Bacteria blight has been known in Asia for a century but only became epidemic in the 1960s, when Green Revolution hybrids proved highly susceptible to Xoo. As high-yield varieties became more popular, Xoo rapidly evolved to target them. In much of India and southeast Asia farmers lost up to 80 percent of their harvest. Fearing catastrophe, the International Rice Research Institute (IRRI)—a research center in the Philippines that, with CIMMYT in Mexico created many of the improved varieties for the Green Revolution—looked for rice varieties that shrugged off Xoo. Researchers found a resistant strain, which they named TKM6, in southern India. By 1969 IRRI had created a resistant hybrid with TKM6 genes. But Xoo quickly mutated, as bacteria will, and the TKM6 hybrid was susceptible to the mutated version of Xoo. As before, the successful bacterial strain replaced the others. Three years after the introduction of the TKM6 hybrid, bacteria blight was again a major problem. By collecting local varieties of rice and wild rice throughout Asia, IRRI managed to identify more than a thousand resistant rice varieties, from which it created a succession of hybrids. Each time, Xoo adapted. Only in the early 1990s was IRRI able to develop what might be a durably resistant hybrid, based on a gene from an obscure rice species in Mali. The gene triggers a novel biochemical mechanism that seems to make the plant's natural defense system more effective. Field trials began in 2000.[32]

Conserving Agricultural Biodiversity

Recognizing the role of agricultural biodiversity in plant breeding, nations have accelerated the collection of seed samples—accessions, as they are known. As might be expected, the biggest such *ex-situ* repository is the at least 320,000 accessions in 155 botanical families at Vavilov's home institute in St. Petersburg, now named in his honor the N.I. Vavilov Institute of Plant Industry.[33] The largest collection of maize resides at CIMMYT's Wellhausen-Anderson Plant Genetic Resources Center, a two-story concrete refrigerator built in 1996 that contains 17,000 accessions of maize and teosinte (a wild relative of maize), as well as 130,000 of wheat, including bread wheat, durum wheat, triticale (a hybrid of wheat and rye), and wild wheat varieties.[34] Scores of other, smaller *ex-situ* conservation efforts exist, many of them coordinated by one of CIMMYT's sister laboratories: the International Plant Genetics Research Institute, in Rome.[35]

Genetic erosion is not restricted to cereals. In the rush to adopt better-yielding breeds of vegetable, for example, more than three-quarters of Europe's traditional varieties have vanished.

Such repositories are universally regarded as essential. But in recent years belief has grown that they are not enough. Although collections are stored in refrigerated facilities, the seeds remain viable only for limited times; as a result, they must be periodically "regenerated"—planted in fields to create new generations of seeds. Alas, both storage and regeneration are costly. And the ability of genebanks to perform these tasks has proven vulnerable to economic and political vicissitudes. The Vavilov Institute, to cite a prominent example, barely made it through the 900-day siege of St. Petersburg (then called Leningrad) during the Second World War. Emaciated and freezing in the unheated building, Institute botanists burned their desks to keep the collections from freezing. So convinced were researchers of the seed bank's importance to the future of humankind that nine starved to death rather than eat the mounds of grain and potatoes around them.[36] Despite this sacrifice, the Institute is again at the edge of ruin.[37] The end of the Soviet Union left it without enough funds to pay staff or maintain its collections. In the late 1990s, researchers discovered that its potato collection, the world's largest, was infested with disease. With no watering or soil-fumigation system, the institute could do little about the problem. Fortunately, an ad-hoc group from Cornell University, the Mlochow Research Center, the Wallace Genetic Fund, and the U.S. Department of Agriculture stepped in to save the potato accessions.[38] But other collections there continue to languish.

Samples of maize await testing in CIMMYT's breeding laboratories outside Mexico City.

Even when gene banks function perfectly, their samples amount to snapshots of crops as they existed on the day of collection. But traditional crops constantly evolve. As farmers choose seed they prefer for the next year's planting, they select among them, and the crop changes in a Darwinian process, guided by human hands. As a result, the traditional varieties grown today are different from those grown in the past, even though they have been cultivated without interruption for centuries. "What you see in the fields is a process that takes place over time," says CIMMYT researcher Mauricio Bellon. "And that process cannot be captured and put into a refrigerator."

In addition, the frozen samples of seed corn in a repository are more readily used if people continue to grow them. Because of the vast number of wheat accessions, for example, plant breeders would have had difficulty searching for varieties resistant to Russian wheat aphid if they had not been tipped off by Iranian smallholders, who had observed this wheat growing in infested fields. The need for local knowledge is even greater if breeders are seeking varieties that grow well in specific soil types or climates. Without farmers' expertise, researchers must work almost randomly, testing hundreds or thousands of varieties—a long and expensive project. Biotechnology is sometimes touted as the way humankind will create new crops, but even the most enthusiastic molecular biologists do not regard their work as able to replace *in-situ* conservation. "*In-situ* is like insurance," says Marilyn Warburton, a CIMMYT molecular biologist. "We believe we can do wonderful things in the lab, but there's no way I'd want to abandon what's in the field."[39]

Despite the widely recognized importance of both local varieties and local knowledge, they are slipping away in all the Vavilov Centers—as Amado Ramírez Leyva discovered when he traveled through Oaxaca. Born into a small town of Mixtec Indians, he grew up eating tortillas handmade by his mother—indeed, his household chores often consisted of grinding the maize for them. His father was a carpenter in town, but Ramírez Leyva spent a lot of time as boy on his maternal grandfather's farm, working the fields and listening to stories. "We are men of maize," the old man often told him, echoing a common sentiment in southern Mexico. "We made maize, and it made us."[40] But Ramírez Leyva was a bookish, intellectual child. Despite all the stories and admonitions, he says now, it was only after spending time in Mexican villages as an adult that he fully realized what the old man had been talking about.

A Community Effort

Maize, according to Arturo Warman, an anthropologist at the Mexican National Autonomous University, is entirely a "cultural artifact."[41] It does not exist in the wild and can only survive if sown and taken care of by human beings. The ancestors of wheat, rice, millet, and barley resemble their domesticated descendants. By contrast, maize almost certainly descends from a mountain grass called teosinte that does not look much like maize (teosinte has many thin stalks, whereas maize has a single thick stalk). And teosinte grain, unlike that of wild wheat and rice, is unfit for consumption—its "ears" consist of a few hard seeds and are scarcely an inch long.[42]

The grain in wild grasses develops near the top of the stem. When it is mature, the stem spontaneously breaks up (shatters, in the jargon), letting the seed fall to the ground. In wild wheat and barley, shattering is blocked by a relatively common single-gene mutation. The change is highly disadvantageous for the wild plant but facilitates its harvest by humans. About ten thousand years ago in the Fertile Crescent, the discovery and planting of nonshattering grain began agriculture. Like other grasses, teosinte shatters, but there is no known nonshattering variant. In addition, the grain is wrapped in a hard case called a "glume." To make the leap from teosinte to maize, Hugh Iltis, an emeritus maize researcher at the University of Wisconsin, postulated that Indians must have found a strange, wholesale mutation of teosinte, recognized its agricultural potential, and then added and subtracted many additional features through centuries of breeding. So different is modern maize from teosinte that scientists believe it was the outcome of a bold act of conscious biological manipulation — "arguably man's first, and perhaps his greatest, feat of genetic engineering," Nina V. Federoff, a geneticist at Pennsylvania State University, wrote in 2003.[44]

"We are men of maize," the old man often told him, echoing a common sentiment in southern Mexico. "We made maize, and it made us."

Archaeological and genetic evidence suggests that the first steps toward modern maize occurred in the highlands of Mexico between five and ten thousand years ago.[45] Although maize may have originated in the slopes of south central Mexico, the focus of development was in the country's deep south, in what are now the states of Oaxaca, Chiapas, and Guerrero. In these ecologically diverse areas, Indian farmers bred scores of "landraces" of maize, each chosen for its taste, texture, color, and suitability for a particular climate and soil type. (A landrace is a family of local varieties, each of which is sometimes referred to as a "cultivar," a cultivated variety.) To people accustomed to thinking of maize in terms of the darker or lighter yellow kernels of corn on the cob, the resultant efflorescence of diversity in Mexican maize is startling. Red, blue, yellow, orange, black, pink, purple, creamy-white, and multicolored—the jumble of colors of Oaxacan maize reflects the state's jumble of cultures and ecological zones. One area may have maize with cobs the size of a baby's hand and little red kernels no bigger than grains of rice that turn into tiny soft puffs when popped; next to it will be maize with cobs almost half a meter long and great soft kernels used mainly to float in soup like croutons. "Every variety has its own special use," says Ramírez Leyva. "This one is for holidays, this one makes tortillas, this one for *niquatole* (a kind of maize gelatin)."

About 50 genetically distinguishable maize landraces have been identified in Mexico, of which at least 30 are native to Oaxaca, according to Flavio Aragón Cuevas, a maize researcher at the Oaxaca office of the National Institute for Forestry, Agriculture, and Fisheries Research (INIFAP).[46] The landraces are like families, each with scores of cultivars—maize researcher H. Garrison Wilkes hazards the guess that as many as 5,000 cultivars may exist in Mesoamerica.[47] (An alternative estimate comes from CIMMYT's genebank, which holds more than 13,000 different maize accessions from around the world, each of which is supposed to represent a cultivar. But because the samples have been collected over time, some are undoubtedly duplicates.)[48] In 1998 CIMMYT researchers identified 37 cultivars in just four small areas of Guanajuato state, a part of Mexico not particularly noted as a center of agricultural diversity.[49] Complicating attempts to create an exact tally, many cultivars lack distinguishing names; indeed, the cultivar called "red maize" in one village may not be the same as the "red maize" in the village next door. Aragón Cuevas has been cataloguing Oaxacan maize since 1997 and expects the task to continue for years to come; he is also working on beans and squash. "We have many different types of soil and climate here," he says. "But the main reason for the diversity is the different ethnic groups—they maintain the landraces."

Mexican landrace maize is inseparable from its creators, according to Hugo Perales, an agronomist at the thinktank Ecosur, in Chiapas.[50] Maize is open-pollinated—it scatters pollen far and wide. (Wheat and rice plants, by contrast, usually pollinate themselves.) Because wind frequently blows pollen from one small maize field onto another, varieties are constantly mixing. "Maize is terribly promiscuous," Perales says, laughing. Uncontrolled, open pollination would, over time, create a single, relatively homogeneous population. But it is not uncontrolled, because farmers carefully select the seed they will sow in the next season—and generally do not choose obvious hybrids. Thus there is both a steady flow of genes among maize landraces and a force counteracting that flow. "The varieties are not like islands, carefully apart," he says. "They are more like gentle hills in a landscape—you see them, they are clearly present, but you cannot specify precisely where they start."

As a result, he emphasizes, one cannot separate the diversity of maize from the people who create it. The crop evolves through the multiple individual choices of the people who work a network of small farms. "It is like a community effort," he says. "The diversity that the breeders depend on is the creation of an entire culture."

The farmers who breed and protect maize perform a service for the rest of the world, but this service comes at a price. Oaxaca had 340,000 farms in 1991, the most recent year for which census data are available.[51] About two-thirds of them occupied less than five hectares—unviably small by the standards of many developed nations. Most landrace maize is grown on these farms, partly because of tradition and partly because they are usually in areas that are too high, too dry, too steep, or too exhausted to support high-yield varieties (or owned by farmers too poor to afford the necessary fertilizer). As if being grown on tiny farms in poor conditions weren't enough, landrace maize is frequently less productive than modern hybrids; a typical yield is one to two tons per hectare, whereas Green Revolution varieties in Oaxaca reap between three and six tons per hectare.[52]

The meager harvests of landrace maize can rarely be brought to market because farm villages are often hours away on bad roads from the nearest large town. But even when farmers try, the effort is often of little use: modern hybrid maize is much cheaper. Incredibly, maize from the United States is cheaper in Oaxaca city than maize from the hillside villages a few miles away. The reasons are multiple, but one major factor is high subsidies to the 424,000 U.S. maize farmers – about 22 cents a bushel, according to one conservative estimate. Since this is about a tenth of the cost of a bushel, the subsidy gives an enormous price advantage.[53] On top of that, U.S. corn belt farmers have more productive soil and growing conditions. They also have enormous indirect subsidies from large-scale U.S. public-sector agricultural research. On the other side of the border, Mexicans usually prefer the taste of local maize, but Mexican farmers can rarely gain any advantage from it. Much of Mexico's maize crop is sold to large industrial maize-flour producers, who will not pay extra for traditional varieties.[54]

Perversely, government policies have increased the burden on poor farmers. The North American Free Trade Agreement called for a gradual lowering of tariff barriers on agricultural goods, including corn. As planned, this would have led to a slow reduction in the price of maize, as surplus U.S. maize came into Mexico. But in 1996 the Mexican government, well ahead of the NAFTA schedule, abruptly eliminated almost all restrictions on imports. In addition, Mexico was one of the few countries willing to import the United States' bumper crop of

Because wind frequently blows pollen from one small maize field onto another, varieties are constantly mixing. "Maize is terribly promiscuous."

genetically modified maize without question. The unsurprising result: maize imports almost quintupled between 1991 and 2001.

At about the same time, Mexico eliminated the National Company of Popular Subsistence (CONASUPO).[56] Founded in 1965, CONASUPO provided price supports for 11 staple crops, maize among them. It bought those crops at guaranteed prices, which aided low-income farmers, and then sold them at subsidized prices in thousands of CONASUPO shops to low-income consumers. At its peak in 1981, CONASUPO bought two-thirds of the national harvest. (The maize was stored in distinctive, cone-shaped concrete silos, hundreds of which stipple rural Mexico to this day.) The agency was run during the late 1980s by Raul Salinas de Gortari, the famously corrupt brother of then-president Carlos Salinas de Gortari. Multiple scandals erupted on Salinas's watch. Shaken, the next president cut back and then eliminated CONASUPO's price-support programs for farmers. (CONASUPO itself was eliminated at the end of 1999.) In a few short years, small farmers lost their principal market.

Worse, the same years saw the rise of Maseca, a Mexican food-products conglomerate founded by a long-time Salinas backer. Maseca sells dried maize flour (*masa seca*, which gives the company its name) directly to consumers. Naturally, it acquires maize at the lowest possible prices, which means that it buys almost exclusively from giant agrobusiness concerns in Mexico and the United States. Thus smallholders reeling from the disappearance of CONASUPO found Maseca bringing in cheap industrial maize, much of it imported, to every village in the nation. According to Wilkes, Maseca and other large producers have been able to take advantage of indirect subsidies, such as special tax rules, free shipping from border inspection stations to processing plants, and expedited regulatory procedures. When inflation is taken into account, maize prices have fallen by three-quarters in the last 15 years.[57]

As their livelihoods vanished, farmers abandoned their land in droves; between 1994 and 2000, the harvested acreage in Mexico devoted to maize fell by 13 percent.[58] Whole villages were depopulated.

Angelina Castellano cooks breakfast tortillas in a cooking shack on her family's small plot in highland Mexico.

Many men slipped across the border to work in the United States, from where they send money to wives and children left behind. They return when they can, and many are slowly building the houses to which they hope to retire after striking it rich. Half-finished cement-block houses dot the landscape, steel reinforcing rods sticking out of the rooflines like rooster combs. Disappearing with the inhabitants are the native landraces of maize, beans, and squash.[59] No precise tallies of the loss exist, but the activist group Genetic Resources Action International has estimated that 20 percent of the varieties known in 1930 have vanished in their entirety.[60]

In developed nations, farmers have mounted sophisticated lobbying campaigns to win government support. This is difficult in southern Mexico, where many small landholders do not speak Spanish. San Juan Chamula, a mountain town in central Chiapas, is an example. Located not far from the colonial city of San Cristóbal de las Casas, it has a white, 16th-century church with a brilliant blue interior that is a popular tourist destination. But beyond the English-speaking owners of souvenir kiosks in the cathedral square, most of the 44,000 inhabitants of Chamula scratch a living from the dry mountain slopes outside town. Almost all are Tzotzil Indians; in 1995, the most recent date for which census data are available, about 28,000—almost two-thirds—of them did not speak Spanish.[61] The overwhelming majority of Chamula's people are maize farmers. Typically, they grow two to three landraces, of which the most common are the various types of *zapalote chico*. Sprawling beneath the stalks are huge, pale green squash, a local type called *chilayote*. According to a recent study by the agronomist Perales, 85 percent of the farmers plant the same maize landraces as their fathers, varieties that have been passed on for generations.[62] By local standards, Chamula is relatively prosperous—an average household has almost 10 hectares. Emboldened by the furor over the Zapatista guerrilla movement in the nearby mountains, Chamula farmers have actively demanded services like electricity and irrigation. Many have received them, Perales says, but in the process the Tzotzil have become a target of official ire. "If they don't push the government, it says they are passive and indolent," Perales says. "If they do push, it says they are greedy. They can't win."

The difficulties faced by smallholders in southern Mexico are far from unique. Although the details differ, the same problems afflict rural farmers in all of the Vavilov Centers. Unable to afford new techniques, they watch helplessly as their livelihoods vanish. Policies geared to the needs of metropolitan areas drive down prices, a boon for countless millions of urban poor. But they are also inadvertently reducing agricultural biodiversity. In the long run, genetic erosion could have negative consequences for agricultural systems around the world, not least among them sharp price increases in food.

In Mexico, genetic erosion is a "cultural tragedy," in the opinion of Ramírez Leyva. If properly made, Ramírez Leyva says, tortillas made from one village's maize will not taste like tortillas from another village's maize—and indeed the eight varieties at Itanoní, his tortillería, are strikingly different. "For thousands of years we ate tortillas and knew exactly where and who we were," he says. "Now the Mexican government has been waging war against the tortilla—for that is what they have been doing, whether they know it or not—and in just 30 years they have almost managed to destroy it all. It's as if you couldn't get good wine in France."

Yet, he insists, preserving maize diversity cannot be a matter of trying to recapture the past. "We live in an age of technology and global trade," he says. "I don't want to give up my cell phone. I want to eat Chinese food sometimes and let my children play Nintendo. What we need to find in the spaces that globalization allows us is the possibility

"Now the Mexican government has been waging war against the tortilla—for that is what they have been doing, whether they know it or not—and in just 30 years they have almost managed to destroy it all. It's as if you couldn't get good wine in France."

of preserving old virtues in a new way. I believe there are many ways of doing this, and that I have found one of them."

From the Stomach to the Heart

Although Ramírez Leyva wants to preserve traditional varieties, the chain of stores he is attempting to establish is mainly an attempt to implement what James Boyce, of the Political Economy Research Institute at the University of Massachusetts, Amherst, describes as the Reverse-Sinclair Effect. The name comes from Upton Sinclair, author of *The Jungle* (1906), an international bestseller about workers in the Chicago meatpacking industry. The novel's graphic description of the appalling conditions in slaughterhouses led to the passage of the first U.S. food-inspection laws—a reform that Sinclair himself viewed with some ambivalence. He had intended the novel to create sympathy for the exploited workers in the meat industry; instead, his readers had become indignant about the meat. Sinclair aimed at the public's heart, he reportedly remarked, but hit it in the stomach. Ramírez Leyva is trying the opposite: by aiming at his nation's stomach, he wants to hit its heart. If a chain of gourmet tortillerías can help remind Mexicans of the value of their culinary heritage, Mexicans may be more willing to value the custodians of that heritage: the country's millions of small farmers.[63]

Ramírez Leyva took a while to arrive at this notion. When he moved back to Oaxaca, he was still unsure of what he wanted to do. For two years he directed a government agricultural-assistance project. It failed utterly, he says, because it implicitly relied on—indeed, perpetuated—what he came to believe was a dysfunctional relationship between smallholders and the central government. Distrusting the government to follow through on its promises (correctly, in Ramírez Leyva's opinion), farmers simply promised allegiance to whichever political faction could give them the largest immediate financial payoff. Rural aid, in other words, had become little more than vote-buying. Among the many problems of this policy, Ramírez Leyva believed, was that it kept rural populations in a convenient state of dependence. And it implicitly abetted the destruction of the traditions that have characterized Mexican society for centuries.

Influenced by the calls of the Zapatista guerrilla movement to increase the political clout of the poor, Ramírez Leyva decided that the best way to help was to invent a mechanism for farmers to extricate themselves from the clutches of a corrupt government. As a model, he looked to... Starbucks. "By franchising distribution centers for good maize," he says, "we could offer to people all over Mexico and the world a product of the highest quality that is the result of a historically significant interaction between ethnic groups and maize." Like Starbucks, the chain of Itanonís he envisions would bring foodstuffs from poor countries directly to middle-class consumers who can pay a premium for higher quality. Unlike the coffee chain, though, each Itanoní will deal directly with maize growers, rather than international buyers, guaranteeing them reasonable prices. "I think it could work," he says. "After all, maize has more flavor and smells better than coffee."

Similar schemes to implement the Reverse-Sinclair Effect have sprung up in Mexico and around the world. One potentially important Mexican project is just getting on its feet. In 2003, the National Association of Campesino Marketing Organizations (ANEC), a consortium of more than 200 smallholder cooperatives founded seven years before, began planning what it hopes will become a national network of maize processors controlled by farmers themselves. Like Ramírez Leyva, ANEC hopes to link rural producers and urban consumers through a chain of tortillerías that sell local varieties. The two projects have some important differences, though. First, ANEC will aim at the larger market of less affluent consumers. Second, it will concentrate more on local production than on specific local landraces. Third, it will try to launch its operation on a larger scale from the beginning by obtaining financial support from the government, a course that Ramírez Leyva has rejected in favor of Silicon Valley-style entrepreneurial expansion from the proverbial garage.

Maize is not the only crop with traditional varieties that are the subject of market-based preservation efforts. In Chiapas, several cooperatives of small coffee growers are marketing the state's unusual varieties of coffee through a chain of cafés that has spread into the western United States.[64] Adriana Valcarcel Manga, of Cuzco, Peru, has slowly managed to create a market for amaranth, a native grain that was on the verge of extinction, by selling it to tourists and to the Peruvian middle class.[65] (Even more would exist, but such enterprises are perennially short of capital and frequently need outside assistance.)

Such efforts are not confined to Third World nations: Jim Gerritsen, of Presque Isle, Maine, has resurrected some of northern

Maine's potato heritage by raising and selling "heirloom" seed potatoes to gardeners. ("Heirloom" is an upscale term for "traditional cultivar.") Nor are they confined purely to crops: in the salt wetlands of Algarve, Portugal, Joao Navalho is protecting endangered shorelines by bringing back the thousand-year-old practice of harvesting salt in small, shallow pans, a practice which had almost vanished in an era of industrial salt mines.[66] (The latter two stories are recounted in *The Pleasures of Slow Food* by Corby Kummer, a 2003 book about efforts to restore the world's culinary heritage.)

A related approach was adopted by Kent and Diane Whealy, who have been working to preserve heirloom fruits and vegetables from extinction since 1975. In that year, they established the Seed Savers Exchange, a nonprofit organization with 8,000 members that sells traditional varieties in a seed catalogue. To produce the seed, Seed Savers grows more than 18,000 rare vegetables and fruits—more than 4,000 types of tomato alone—on its farm in Decatur, Iowa. An annual convention of members takes place every July. With some financial backing, one can readily imagine establishing similar cooperatives in other nations.[67]

Some preservation efforts have been backed by Slow Food, an Italy-based "movement for the protection of the right to taste." With 60,000 members around the world, Slow Food sponsors the Ark of Taste, a "massive project to identify and catalogue (the alas increasingly numerous) products, dishes, and animal breeds in danger of disappearing." The movement economically supports efforts to preserve individual crops through Slow Food Presidia and creates publicity for its efforts with the annual Slow Food Awards. In 2001, Adriana Valcarcel Manga, the amaranth grower, was a recipient. Calling itself a movement for "eco-gastronomy," Slow Food argues—like Ramírez Leyva—that much of what gives people pleasure is "connected to the equilibrium we manage to preserve (and in many cases revive) with the environment we live in."[68]

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What We Can Do: Five Approaches

In addition to directly backing efforts to market traditional crop varieties, governments and nongovernmental organizations have at least five other ways to help agrodiversity projects: regulation of labeling, crop improvement, eliminating perverse incentives, arranging payments for uncompensated services, and increasing social capital. In different ways, all attempt to invoke the Reverse-Sinclair Effect—that is, they attempt to bolster the perceived value of traditional landraces in an attempt to better the lives of the people who grow them.[69]

1) Labeling

One surprisingly useful approach is to guarantee a product's bona fides with a label: a collective trademark, a denomination of origin, a certificate that it has passed a test of quality. In the West, labeling dates back at least to the "cloth marks" created by local gentry in medieval England.[70] In those days, the cloth sold to merchants came rolled into enormously long bolts; the mark guaranteed the quality of the cloth not visible. The range of qualities that can be guaranteed is lengthy: processes (grown with "organic" methods, for example), ingredients (made without monosodium glutamate), territories (pure Vermont cheddar), and so on.

Because products can readily be distinguished in quality or kind by their origin, government-controlled certificates of origin have become common in Europe, Japan, and, increasingly, the United States. Delineating the limits of a producing region helps prevent outsiders from diluting a product's reputation with inauthentic and inferior versions. Perhaps the most famous examples come from France, which in 1935 created the National Institute for Denominations of Origin, the agency that established the official boundaries of wine regions like Bordeaux and Burgundy.[71] If a region has a strong reputation, it may impose quality controls to keep bad producers inside the region from taking a "free ride" on its reputation. In European Union nations, rules lay out the processes that producers must follow to earn the right to sell their products under a particular name. Thus cheesemakers must make cheese with specified levels of fat, age those cheeses for given periods before sale, and so on. In both cases legitimate growers know that copycats will not be able to take advantage of their efforts and so will invest in maintaining quality and reputation.

Passersby stop outside the tortilleria, arrested by the perfume of toasting corn and then, as they come closer, by the sight of the women working over the clay stoves.

These systems can be difficult to establish, because they must define the distribution of the resource and the relevant group that is associated with it. But there is little doubt that they have helped maintain the traditions of many areas. Working with the Mexican government's department of the environment, several researchers are seeking to create a denomination for Oaxacan landrace maize (Ramírez Leyva is part of this group). Only traditional varieties grown by traditional means will be eligible.[72] In this regard, recent reports of the appearance of transgenic maize (that is, maize that has been genetically re-engineered) in southern Mexico may pose a problem. The initial discovery, described in the journal *Nature* at the end of 2001, was withdrawn months later by the journal's editors. Nonetheless, it is widely believed that U.S. transgenic maize, sold at subsidized prices in state-affiliated stores, is beginning to be planted in the area by farmers who don't know what it is. In consequence, the proponents of creating a denomination believe they must work quickly—the denomination will provide both a means of educating farmers about transgenics and a financial incentive for farmers to avoid them.

2) Crop improvement

A second role for government and nonprofits is to help improve traditional varieties. Perhaps the most common form of this assistance is known as "participatory plant breeding." First promulgated in the early 1980s by Robert Rhoades, a University of Georgia anthropologist, and Robert Booth, a plant pathologist now at the International Institute for Tropical Agriculture in Nigeria, the system moves plant breeding as far as possible from the laboratory to farmers' fields.[73] Instead of being handed new strains, farmers are asked to test them in a wide variety of circumstances, selecting the ones they like best. The goal is to produce improved seed that retains the characteristics most important to local people.

Oaxaca is the site of one such program, which focuses on improving landrace maize without sacrificing the characteristics that give it an identity.[74] In 1997, INIFAP researcher Aragón Cuevas and his coworkers collected 152 samples of five landraces from 15 communities in different ecological zones throughout the state, looking for diversity in color, height, grain texture, kernel and cob size, and cultivation cycle. All were grown in farmers' fields in each community to learn how they would perform in different circumstances. At the end, families were asked to select the best performers. "The women were more adventurous than the men," Aragón Cuevas says. "They thought in terms of maize that was better to consume at home, whereas the men looked for uniform maize that they thought would do better on the market." INIFAP grew and distributed seed from the winners, which is now being used by about 30,000 farmers, including those who supply maize to Itanoní.

As Aragon Cuevas acknowledges, the program's success may have a downside. As farmers put aside less productive varieties for improved landraces, the total number of cultivars will go down. Nonetheless, he says, "losing a little bit is much better than total displacement."

Delineating the limits of a producing region helps prevent outsiders from diluting a product's reputation with inauthentic and inferior versions.

3) Removing perverse incentives

However inadvertently, government policies in both poor and rich nations work against agricultural biodiversity. Mexican tortilla factories, for example, can obtain government subsidies only if they certify that their products are of a uniform color, texture, and taste. Because the essence of landrace maize is its lack of uniformity, tortilla factories are often unable to purchase it, especially when it is a nonstandard color like red, purple, or pink. Producers are thus deprived of an important market. Even when factories do buy landrace maize, they are required to mix it with other maize, again in the name of guaranteeing uniformity. This makes it impossible for farmers to compete on quality. Instead, the most productive farmer will reap the greatest sales. Landraces usually being less productive, their producers, again, are handicapped.

Trade policies in wealthy nations accentuate these difficulties. Subsidies to farmers in the United States and Europe are often decried for their effect on exports from poor nations. If, say, U.S. cotton price supports rise, African farmers won't be able to sell as much cotton to U.S. textile firms. But the impact of subsidies in rich nations also reaches *inside* poor nations, with even greater impact. Because subsidies can insulate farmers in wealthy countries from the price decreases that usually flow from supply increases, they encourage the export of cheap agricultural goods. In southern Mexico, as mentioned, U.S.

maize is less expensive than maize from farmers in the region. Reducing subsidies might not cure this problem altogether, but it would decrease the price advantage.

Some activists have suggested carving out an exception to trade rules that would permit countries to restrict imports if they diminished agricultural biodiversity.[75] World Trade Organization rules allow for countries to put certain products into restricted "green boxes" if their import would harm agricultural research, pest and disease control, agricultural inspection, crop insurance, natural disaster relief, or water-conservation programs. Poor countries are seeking to expand the green box into a "development box" that would permit agricultural subsidies targeted at the poor. In theory, a similar exemption could be used to promote traditional varieties and wild relatives of crop species. An example is the European Union policies that restricted the trade of seed to certified varieties; because they implicitly forbade the exchange or sale of heirloom and traditional varieties, the EU, after a protest, created an exemption for local varieties.[76] This practice does not run into the same difficulties as providing direct awards does because it doesn't require establishing the value of *in-situ* biodiversity. Nor does it try to create payment mechanisms. But trade negotiations are notoriously intractable. "Fighting something through the WTO is a tough course," says Peter Rosset, co-director of of the Institute for Food and Development Policy (Food First), an agricultural policy research center in Oakland, CA.

4) Paying for currently uncompensated services

From correcting policies that work against *in-situ* conservation, the next step is to examine policies that actively reward it. The intellectual justification of this approach is simple: the smallholders who maintain agricultural biodiversity are, in effect, providing genetic insurance for the rest of the world. At present, they are providing this service without compensation, a kind of reverse subsidy from poor producers to affluent consumers. If a service is valuable enough to maintain, as this one is, it should be rewarded; otherwise, farmers will continue abandoning traditional varieties for better opportunities. Private or government agencies could thus invest in development efforts—irrigation, for example—that would increase productivity of local maize farms. Another, equally useful approach would be to improve schools and health services, which would help retain farmers in rural areas.

The obvious difficulties with this prescription are those of assigning value to *in-situ* biodiversity and figuring out how to pay for it. Little economic research has been done on the first question. Because many of the Vavilov Centers are in extremely poor areas, though, the lack of research may not be a big problem, at least initially—any payment at all could have an enormous impact. Much more pressing is the need for a long-term funding source that will collect funds from rich nations and disburse them to farmers with traditional varieties in poor nations. One possibility is the Global Environment Fund. Established in 1991, the GEF was revamped in 1994, after the summit in Rio de Janeiro that produced the Convention on Biological Diversity. The GEF became the financial instrument of the convention; almost 40 nations now make annual pledges to it. GEF projects are implemented through the U.N. Development Program, the U.N. Environment Program, and the World Bank. Its efforts thus far have focused on preserving "natural" biodiversity, but the GEF has begun to consider adding agricultural biodiversity to its mandate.

After obtaining a funding source, it will be critical to establish a payment system that does not unintentionally harm the people it is supposed to reward. "Payment for ecological and genetic services is an ethical principle," says Rosset of the Institute for Food and Development Policy. "The problem is that when money falls from heaven into a poor community, it often ends up accentuating the power and wealth differences in the community. It can even lead to violence." Nor is handing the funds to a corrupt central government the answer, he says. Problems between communities inevitably arise when only some are selected as beneficiaries. "These payments are very difficult for outsiders to arrange," he says. "That doesn't mean they're unimportant, though. They're just difficult."

5) Increasing social capital

Essential to all of these measures is the ability to increase the prestige of traditional varieties and the people who work with them. In the 1960s the Italian government took steps to protect wine growers by establishing an official denomination system, replacing several groups of unofficial consortia that had existed for decades.[77] The intent of the system was in part to protect distinctive Italian wine varieties like *nebbiolo*, *sangiovese*, and *trebbiano*. But the reason that those varieties remained to protect was that in Italy, especially in northern Italy, grape farming is a high-status occupation. Indeed, many Italian nobles are farmers with small plots of land. By contrast, little status clings to the nation's olive growers, though olive oil is surely as emblematic of Italian culture. Unsurprisingly, the nation's olive production is increasingly standardized and mechanized.[78] Recently, though, boutique olive-oil growers have emerged, explicitly basing their appeal on saving regional varieties, which in turn have become fashionable.

Boosting social status cannot be done automatically, especially when growers belong to despised social groups. Simply increasing income, though a useful step, is not enough, as the history of human snobbery attests. The Tzotzil of San Juan de Chamula, in Chiapas,

Essential to all of these measures is the ability to increase the prestige of traditional varieties and of the people who work with them.

have managed to improve their fortunes, but they are still looked down upon by their urban neighbors. Festivals, awards, exhibitions, and media campaigns can be helpful, Rosset suggests. "Look at how many California towns have their Asparagus Day or their Sunflower Show," he says. "It's a way of increasing social esteem."

The Best Tortillas in Mexico

According to Ramírez Leyva, increasing the value of agricultural biodiversity is a matter of education, or, rather, re-education. Most people already know the virtues of their birthplace, he says. The task is to remind them. Mexicans, he points out, eat tortillas every day; they are intimately comfortable with them. So familiar are they with tortillas that they hardly think about them. "With Itanoní I make them remember," he says. "I tell them how you make a good tortilla. They already know this, they already think this, but they forgot."

The rules for making a true tortilla are indisputable and known throughout Mexico, he says. Tortillas must be made from maize from a single field; like a glass of wine, a tortilla should carry the flavor of its native place. First the dried kernels have their thin, translucent skins removed in a bath of lime and water (a process with its own special verb, *nixtamalizar*). Then they are stone-ground into a light, slightly sticky paste with a distinct maize fragrance. The paste, known as *masa*, has no salt, spices, or preservatives. It must be cooked within a few hours of being ground, and the tortilla must be eaten soon after it is cooked. Hot is best, he says, perhaps folded over with mushrooms or squash flowers in a *tlacoya*.

Passersby stop outside his tortillería, arrested by the perfume of toasting corn and then, as they come closer, by the sight of the women working over the clay stoves. Ramírez Leyva eagerly proselytizes for his tortillas, showing people the five different choices available that day. Most people have never heard the names of these landraces—*criollos*, in Spanish. Some begin weighing their choices. "Half the secret of Starbucks is knowing that they sell 10 different kinds of coffee," Ramírez Leyva says. "If you know something is available in many different varieties, you no longer think of it as an undifferentiated commodity. Suddenly you must have an opinion."

One woman marches firmly over to the tortillas made from *belatove*, a landrace with reddish purple kernels that have a layer of yellow at the base. "These are the ones I want," she says. "I had them all the time at my grandparents' house. I thought they'd disappeared. I couldn't believe my eyes when I saw them here in the middle of the city."

Charles C. Mann's book, 1491: The Americas Before Columbus, *will be published by Alfred A. Knopf in winter 2004. A correspondent for* The Atlantic Monthly *and* Science, *he is the author or co-author of four previous books, including* Noah's Choice: The Future of Endangered Species *(Knopf). His writing appears in* The Best American Science Writing 2003 *and* The Best American Science and Nature Writing 2003.

Like a glass of wine, a tortilla should carry the flavor of its native place.

Notes

[1] Itanoní description, plans, history: Author's interview, Amado Ramírez Leyva (all subsequent quotes).

[2] Maize as most important crop: The 2001 maize harvest was 609 million metric tons, according to the database of the United Nations Food and Agricultural Organization. Following maize were rice (592 million mT) and wheat (582 million mT). In one sense, the statistics are misleading: most maize is destined for animal feed, and is thus consumed by humans indirectly, whereas most rice and wheat are consumed directly, though some of the latter are used indirectly as animal feed, liquor, and so on. The FAO database is online at: http://apps.fao.org/default.htm .

[3] Maize's centrality to Mesoamerican culture: Weatherwax, P., *Indian Corn in Old America*, N.Y.: Macmillan, 1954; Warman, A., *La Historia de un Bastardo: Maiz y Capitalismo*, Mexico, D.F.: Instituto de Investigaciones Sociales, UNAM : Fondo de Cultura Económica, 1988.

[4] Impossibility of finding good tortillas: Author's interview, Giorgio de Angeli, Restaurant El Tajil, Mexico, Angeli is the head of the Mexican branch of Slow Food (see below).

[5] Uniqueness of Itanoní: Small tortillerías using local maize and traditional preparation with lime (*nixtamal*) persist throughout rural Mexico, although they are threatened by the less expensive industrial production of Maseca, the large maize-flour and tortilla firm. By contrast, Itanoní is a boutique operation that sells as many as eight different varieties of tortillas, each made from a separate local variety. The difference is akin to the difference between an Italian village café that sells liters of unlabeled local wine and an *enoteca*, a fine wine store featuring the carefully labeled production of the region. As described below, the National Association of Campesino Marketing Organizations (ANEC) is planning to establish somewhat similar shops on a large scale, though without attempting to tap the middle-class gourmet market.

[6] Number of crops: Diamond, J., *Guns, Germs, and Steel: The Fates of Human Societies*, N.Y.: W.W. Norton, 1997, p. 132.

[7] Increasing threat to traditional varieties: A useful brief introduction is Thrupp, L.A., *Cultivating Diversity: Agrobiodiversity and Food Security*, Washington, D.C.: World Resources Institute, 1998.

[8] Southern leaf blight: The full tale of southern maize leaf blight is more complex than this abbreviated account, although the lesson is not. "Never again should a major cultivated species be molded into such uniformity that it is so universally vulnerable to attack by a pathogen, an insect, or environmental stress" (Ullstrup, A.J., "The Impacts of the Southern Corn Leaf Blight Epidemics of 1970-71," *Annual Review of Phytopathology*, 10:37-50, 1972). The source of vulnerability was the method then used to produce hybrid maize. To prevent self-pollination, both parents must be planted in close proximity and the pollen-bearing tassels removed from the male. Because tassel removal is labor intensive, varieties of maize with sterile male tassels were sought. One such variety had the gene Tcms—a gene located, as it happened, not in the DNA in the cell's nucleus but in the smaller amount of DNA in the mitochondria (energy-producing bodies within the cell). By 1970 Tcms was present in an estimated 85 percent of the maize crop. Unfortunately, the Tcms gene also conferred acute susceptibility to a mutated form of *Bipolaris maydis*, until then not a major pest (see the articles in the special Southern Corn Leaf Blight issue of the *Plant Disease Reporter*, 54(12):1099-1136, 1970; Hooker, A. L., et al, "Reaction of corn seedlings with male-sterile cytoplasm to *Helminthosporium maydis*," *Plant Disease Reporter*, 54: 708-712, 1970 [*Bipolaris maydis* was formerly named *Helminthosporium maydis*].) The quick fix was to breed maize with no male sterility, which was rapidly, even heroically accomplished by the U.S. seed industry. But this was a stopgap, because the quality of nonsterile hybrids is hard to control. The industry sought around the world new strains of maize with male sterility, finally finding them in, among other places, Mayorabala maize in Africa (Author's interview, H. Garrison Wilkes, maize biologist, University of Massachusetts, Boston [all quotes]; Fowler, C., and Mooney, M., *Shattering: Food, Politics, and the Loss of Genetic Diversity*, Tucson: University of Arizona Press, 1990, pp. ix-xii).

[9] "It seems incredible": Author's interview, Mauricio Bellon, agricultural economist, CIMMYT (all quotes).

[10] "Some parts": Author's interview, T. Boone Hallberg, biologist, Oaxaca Institute of Technology (all quotes).

[11] Long debate over origin of maize: Kahn, E.J., *The Staffs of Life*, Boston: Little, Brown, 1985, pp. 3-82; Galinat, W.C., "Maize: Gift from America's First Peoples," in Foster, N., and Cordell, L.S., eds., *Chilies to Chocolate: Foods the Americas Gave the World*, Tucson: University of Arizona Press, 1992, pp. 47-60.

[12] *Milpa*: Ewell, P. T., and Sands, D.M., "Milpa in Yucatán: A Long-Fallow Maize System and its Alternatives in the Maya Peasant Economy," in Turner, B., and Brush, S.B., eds., *Comparative Farming Systems*, N.Y.: The Guilford Press. pp. 95-129; Wilken, G. C., *Good farmers: Traditional Agricultural Resource Management in Mexico and Central America*, Berkeley: University of California Press, 1987. A classic early study is Cook, O.F., "Milpa Agriculture: A Primitive Tropical System," in *Annual Report of the Board of Regents of the Smithsonian Institution, Showing the Operations, Expenditures and Condition of the Institution for the year ending June 30, 1919*, Washington, D.C.: Government Printing Office, 1921, pp. 305-326.

[13] Vavilov's work and life: Popovsky, M., *The Vavilov Affair*, Hamden, CT: Archon Books, 1984; Adams, M.B., "Vavilov, Nikolay Ivanovich," in Gillispie, C.C., *Dictionary of Scientific Biography*, Supplement I (Vol. XV), N.Y.: Scribner's, 1978, pp. 505-513.

[14] Description of Vavilov centers: This was Vavilov's final formulation in 1940. His first version of the idea, in 1926, picked out five areas. The number of Vavilov centers crept up as he elaborated his theories, until his 1940 classification, completed the year before his arrest, identified 13 centers in 7 large areas (Adams, M.B., op.cit.).

[15] Critiques of Vavilov's work: The location of Vavilov's centers of diversity reflected his travel itinerary. Two areas he did not visit were the Amazon Basin and sub-Saharan Africa, which some agricultural historians believe should be added (Stephen Brush, personal communication, May 2002).

[16] Green Revolution: Food and Agricultural Organization, *Agriculture: Towards 2015/30*, Technical Interim Report, Rome: FAO, April 2000, chap. 2 (available online at http://www.fao.org/es/esd/at2015/toc-e.htm). Two notes: 1) The figures for food supplies include imports, so should not be taken as other than an approximate indicator of national production. 2) In some respects the historical situation was even worse than these figures make it sound. In the mid-1960s, the "great bulk" of the 56 percent lived in countries with under 2,000 kcal. Meanwhile, 30 percent of the world population (overwhelmingly that of the developed countries) lived in countries with over 2,700 kcal, two thirds of it in countries with over 3,000 kcal. "… a situation of very pronounced inequality" (*ibid*, pp. 20-21). See also, Mann, C. C., "Reseeding the Green Revolution," *Science*, 277: 1038-1043, 1997; Mann, C.C., "Crop Scientists Seek a New Revolution," *Science*, 283: 310-314, 1999.

[17] Impact of Green Revolution: Evenson, R. E. and Gollin, D., "Assessing the Impact of the Green Revolution, 1960 to 2000," Science 300: 758-762, 2003. The article is based on research commissioned by the Standing Project on Impact Assessment of the Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR) and published in Evenson, R. E. and Gollin, D., eds., *Crop Variety Improvement and Its Effect on Productivity: The Impact of International Research* (Wallingford, UK: CAB International, 2003.

[18] Loss of agricultural biodiversity: See, in general, Food and Agricultural Organization (United Nations), *The State of the World's Plant Genetic Resources for Food and Agriculture*, Rome: FAO, 1997, esp. Annex 2; World Conservation Monitoring Centre, *Global Biodiversity: Status of the Earth's Living Resources*, London: Chapman & Hall, 1992, esp. chaps. 24, 27. One of the earliest formulations of the tradeoff between hybrid productivity and genetic diversity is in Wilkes, H.G., and Wilkes, S., "The Green Revolution," *Environment*, 14:32-39, 1972.

[19] Sri Lanka rice: Rhoades, R.E., "The World's Food Supply at Risk," *National Geographic*, 179(4): 74-103, 1991.

[20] Rice in Bangladesh, Indonesia: Hargrove, T.R., *et al*., "Twenty Years of Rice Breeding," *Bioscience*, 38: 675-681, 1988.

[21] "Only one race": Goodman, M. M., "Genetic and Germplasm Stocks Worth Conserving," *Journal of Heredity*, 81:11-16, 1990, at 13. "Within the one maize race used in the United States there were in the early 1900s thousands if not tens of thousands of open-pollinated varieties of maize distributed all over the U.S. Corn Belt. … [Today] it is almost impossible to find a widely used U.S. hybrid

whose parentage can be traced to neither Reid's nor Lancaster's [two widely crossed varieties], and the situation in Europe does not differ greatly. About six inbred lines and their close relatives are represented in a very high percentage—perhaps 70% or more—of all U.S. hybrids" (*ibid*, p. 13).

22 Rice in China: Byerlee, D., *Modern Varieties, Productivity, and Sustainability: Recent Experience and Emerging Challenges* (Mexico City: CIMMYT, 1994), cited in Fritschel, H., *et al*, "Key Trends in Feeding the World, 1970-95," 2020 Vision Synthesis, May 1996, available at http://www.ifpri.cgiar.org/2020/synth/trends.htm (visited June 2002).

23 *Shattering*: Fowler, C., and Mooney, M., *op.cit.*

24 Potato crop diversity: National Research Council (U.S.), Committee on *Genetic Vulnerability of Major Crops*, Genetic Vulnerability of Major Crops, Washington: National Academy of Sciences, 1972, pp. 193-203; Fowler, C., and Mooney, M., *op.cit.*, chap. 2.

25 Lack of large-scale change in genetic vulnerability since 1972: Committee on Managing Global Genetic Resources: Agricultural Imperatives, National Research Council, *Managing Global Genetic Resources: Agricultural Crop Issues and Policies*, Washington, D.C.: National Academy Press, 1993, pp. 66-81. The genetic base of some crops, notably wheat, has increased somewhat, but many minor crops have become less diverse; even wheat, though, still has an "extensively shared ancestry and limited use of exotic germplasm" (p. 80).

26 "We built…": Fowler, C., and Mooney, M., *Shattering…*, *op.cit.*, p. xii.

27 Seven-year lifespan: Duvick, D.N., "Genetic Diversity in Major Farm Crops on the Farm and in Reserve," *Economic Botany*, 38: 161-78, 1984.

28 Pathogens and genetic variety: Committee on Managing Global Genetic Resources: Agricultural Imperatives, National Research Council, *Managing Global Genetic Resources: Agricultural Crop Issues and Policies*, Washington, D.C.: National Academy Press, 1993, pp. 47-84. The classic general source on host-pathogen evolution is Ewald, P.W., *Evolution of Infectious Disease*, N.Y.: Oxford University Press, 1994. Somewhat counteracting the effects of monoculture, many pathogens become less virulent as they become widespread. Others become more virulent, though. Their behavior depends on the mode of transmission: pathogens that are directly transmitted from host to host generally lose virulence, whereas those that require an intermediate vector like an insect generally gain it.

29 Discovery of *Zea diploperennis* and viral resistance: Iltis, H., "New Year's Card Leads to Newly Discovered Species of Enormous Economic Potential," *Innovative Leader* (formerly *R&D Innovator*), No. 103, 1994, available online at http://www.winstonbrill.com/bril001/html/article_index/articles101_150.html (visited July 2002); source of resistance: Wei, W.-H., et al., "Comparative Analyses of Disease Resistant and Non-resistant Lines from Maize x *Zea diploperennis* by GISH," *Botanical Bulletin of the Chinese Academy of Sciences*, 42: 109-114, 2001.

30 *Zea diploperennis* and witchweed (Striga): International Institute of Tropical Agriculture, "Maize Wild Relatives Get a Stranglehold on Striga," *Annual Report 1997*, Ibadan, Nigeria: IITA, online at http://www.iita.org/info/ar97/6-7.htm (visited June 2002). For Striga itself, see Mann, C.C., "Saving Sorghum by Foiling the Wicked Witchweed," *Science 277*: 1040, 1997.

31 Russian wheat aphid: Gollin, D., et al, "Optimal Search in *Ex Situ* Collections of Wheat," in Smale, M., *Farmers, Gene Banks and Crop Breeding: Economic Analyses of Diversity in Wheat, Maize, and Rice*, Norwell, MA: Kluwer Academic Press, 1998, pp. 57-77; Gollin, D., et al., "Searching an *Ex Situ* Collection of Wheat Genetic Resources," *American Journal of Agricultural Economics*, 82: 812—827, 2000; Robinson, J., *Identification and Characterization of Resistance to the Russian Wheat Aphid in Small-Grain Cereals: Investigations at CIMMYT, 1990-92*, CIMMYT Research Report No. 3, Mexico, D.F.: CIMMYT, 1994.

32 Rice-leaf bacteria blight: Mew, T.M., et al, "Changes in race frequency of Xanthomonas oryzae pv. oryzae in Response to Rice Cultivars Planted in the Philippines," Plant Disease, 76: 1029-1032, 1992; Ronald, P.C., "The Molecular Basis of Disease Resistance in Rice," Plant Molecular Biology, 35: 179-186, 1997; Kate, K.T., and Collis, A., "Benefit-Sharing Case Study: The Genetic Resources Fund of the University of California, Davis," Submission to the Executive Secretary of the Convention on Biological Diversity by the Royal Botanical Gardens, Kew, n.d. (available at http://www.biodiv.org/doc/case-studies/cs-abs-ucdavis.pdf , visited June 2002)

33 Vavilov Institute: Krivchenko, V.I., "The role of Vavilov in Creating the National Soviet Program for Plant Genetic Resources," *Diversity*, 16(5): 5-7 1988. The accession count varies from 320,000 to 375,000 in various references, due to uncertainties in the database. The Institute Website puts the tally at 320,000 (http://www.dainet.de/genres/vir/index.htm, visited June 2002).

34 CIMMYT germplasm bank: Author's interview, Suketoshi Taba, Director, Maize Genetic Resources, CIMMYT; see also the CIMMYT gene bank's home page at http://www.cimmyt.org/Resources/Obtaining_seed/Plant_genetic_rc/Wellhausen_Anderson/wellhausen-anderson.htm (visited June 2002).

35 World supply of gene banks: Food and Agricultural Organization (United Nations), *The State of the World's Plant Genetic Resources for Food and Agriculture*, Rome: FAO, 1997, esp. Chap. 3.

36 Vavilov Institute in war: Raeburn, P., *The Last Harvest: The Genetic Gamble That Threatens to Destroy American Agriculture*, N.Y.:Simon & Schuster, 1995, pp. 42-44.

37 Troubles of Vavilov Institute: Food and Agricultural Organization (United Nations), *Russia: Country Report to the FAO International Technical Conference on Plant Genetic Resources (Leipzig, 1996)*, Moscow: FAO, 1995.

38 Potato program at Vavilov Institute: Friedlander, B.P., Jr., "CU and Polish Scientists are Leading Effort to Save Valuable Genetic Archive," *Cornell Chronicle*, 31(41): n.p., 2000.

39 Biotechnology not a replacement: Author's interview, Marilyn Warburton, Molecular Geneticist, Applied Biotechnology Center, CIMMYT (all quotes).

40 "Men of maize": The phrase is common and to some extent literally meant: the third book of the Popul Vuh, the creation story of the highland Guatemalan Maya, says that the gods created humankind out of maize, after unsuccessful previous attempts with clay and wood. Today, it is still common to hear people of Mayan descent in southern Mexico and Guatemala say *somos hombres de maiz*—we are men of maize (Author's interview, Lone B. Badstue, social anthropologist, CIMMYT).

41 "Cultural artifact" and maize history: Warman, A., *La Historia de un Bastardo: Maiz y Capitalismo,* Mexico : Instituto de Investigaciones Sociales, UNAM : Fondo de Cultura Económica, 1988, p. 49.

42 Teosinte description: Wilkes, H. G., *Teosinte: the Closest Relative of Maize,* Cambridge, MA: Bussey Institute (Harvard University), 1967; Wilkes, H. G., "Maize and its wild relatives," Science, 177: 1071-1077, 1972.

43 Teosinte theory: Iltis, H. H., "From Teosinte to Maize: the Catastrophic Sexual Transmutation," *Science*, 222: 886-894, 1983.

44 Arguably: Federoff, N.V., "Prehistoric GM Corn", *Science* 302: 1148-1159, 2003. For alternatives to the teosinte theory, see Eubanks, M., "The Mysterious Origin of Maize," *Economic Botany*, 55:492-514, 2001.

45 Locus of development of maize: Eubanks, M.W., "An Interdisciplinary Perspective on the Origin of Maize," *Latin American Antiquity* 12:87, 2001; MacNeish, R.S., and Eubanks, M.W., "Comparative Analysis of the Río Balsas and Tehuacán Models for the Origins of Maize," *Latin American Antiquity*, 11:3-20, 2000; Piperno, D.R., and Flannery, K.V., "The Earliest Archaeological Maize (*Zea mays* L.) from Highland Mexico: New Accelerator Mass Spectrometry Dates and their Implications," *Proceedings of the National Academy of Sciences*, 98: 2101-2103, 2001.

46 Aragón Cuevas research: Author's interview, Flavio Aragón Cuevas, senior researcher, INIFAP, Oaxaca (all quotes).

47 5,000 cultivars: Author's interview, H. Garrison Wilkes.

48 13,000 maize accessions: Author's visit, CIMMYT.

49 Guanajuato diversity: Aguirre Gómez, J.A., et al., "A Regional Analysis of Maize Biological Diversity in Southeastern Guanajuato, Mexico," CIMMYT Economics Working Paper 98-06, Mexico, D.F.: CIMMYT, see Table 4.

[50] Perales research: Author's interview, Hugo Perales Rivera, Director, Department of Agroecology, ECOSUR (all quotes).

[51] Oaxaca data: *Annuario Estadístico del Estado de Oaxaca*, Aguascalientes, Ags.: Instituto Nacional de Estadística, Geografía e Informática, 1998, pp. 532-568.

[52] Estimated productivity of Green Revolution maize in Oaxaca: Author's interview, Aragón Cuevas. The estimate is roughly confirmed by the calculations of Ackerman, F., et al., that "a 1 percent increase in use of improved varieties was typically associated with an increase in yield of 0.037 tons/ha"and hence a 100 percent switchover is a jump of 3.7 tons/ha ("Environmental Impacts of the Changes in US-Mexico Corn Trade Under NAFTA," unpub. ms., 15 May 2002, p. 36).

[53] U.S. farm subsidies: Food and Agricultural Policy Research Institute, "Farm Security and Rural Investment Act of 2002: Preliminary FAPRI Analysis," 6 May 2002, available at: http://agriculture.senate.gov/Briefs/2002FarmBill/FAPRI.pdf (visited July 2002) (analyzing impacts of 2002 U.S. farm bill); see also, Boyce, J.K., "Ecological Distribution, Agricultural Trade Liberalization, and *In Situ* Genetic Diversity," *Journal of Income Distribution*, 6(2):265-286, 1996.

[54] Economic problems of landrace maize in Oaxaca: Author's interviews, Aragón Cuevas, Bellon, Hallberg, Ramírez Leyva, Wilkes.

[55] NAFTA and Mexican maize: Author's interviews, James Boyce, economist, University of Massachusetts at Amherst; Perales; Peter Rosset, co-director, Food First; Wilkes. Exact figures for U.S. exports to Mexico are at the USDA at http://www.ers.usda.gov/db/fatus/ (visited June 2002). Although the numbers jump around, imports for 1991 were 1,316,066 metric tons; in 2000, the figure was 5,194,328 mT.

[56] CONASUPO history and economics: Yúnez-Naude, Antonio, "The Dismantling of CONASUPO, a Mexican State Trader in Agriculture," Working Paper, Center on Rural Economies of the Americas and Pacific Rim, University of California at Davis, October 2001, at www.reap.ucdavis.edu/working_papers/conasupo.pdf (viewed June 2002); author's interviews, Boyce; Perales; Ramírez Leyva; Wilkes. Mexican agricultural policy, like that of other nations, is complex; I have only touched on it here. CONASUPO was especially targeted at the welfare of *ejidatarios*, farmers whose families had received land in the redistribution after the Mexican revolution of 1910. Until 1991, ejidatarios were akin to sharecroppers, with the government acting as landlord; they were not allowed to dispose of their lands and effectively forced to sell their produce to CONASUPO.

[57] Maize prices in Mexico: I am grateful to CIMMYT technical writer Michael Listman for looking up this figure, and for many other kindnesses during my visits.

[58] Harvested maize acreage: Ackerman, F., *et al*., "Environmental Impacts of the Changes in US - Mexico Corn Trade Under NAFTA," unpub. ms., 15 May 2002, Table 4 (calculated with SAGARPA data). This figure should be used carefully. Because the majority of maize acreage is in large farms, the decline in harvested land largely reflects a switch to other crops by large producers as maize prices fell. Small farmers did leave the land, often for the United States, but their land frequently was then combined into larger operations that planted modern hybrid maize (author's interview, Ramírez Leyva). When the land was unsuitable for industrial farming, families usually kept at least some land in production for subsistence. As a result, the loss of smallholders is not fully reflected in this figure.

[59] Disappearing landraces: In a hypothetical calculation, Ackerman, F., *et al*., suggest that the number of Oaxacan farmers using modern varieties may have jumped from 19.6 percent to 25.7 percent in the 1990s alone. Accompanied by similar changes elsewhere in Mexico, "this would imply a rapid reduction in the use of landraces, which would indeed threaten the genetic diversity of maize in Mexico" (*ibid*, p. 37).

[60] Losses since 1930: Genetic Resources Action International, "The Biotech Battle for the Golden Crop," *Seedling*, October 1996, at http://www.grain.org/publications/oct964-en-p.htm (visited June 2002). Wilkes (personal communication) guesses that the losses for maize might approach 50 percent in the north and 25 percent in the south.

[61] Chamula statistics: *Annuario Estadístico del Estado de Chiapas*, Aguascalientes, Ags.: Instituto Nacional de Estadística, Geografía e Informática, 1998. I am grateful to Hugo Perales for helping me obtain these figures.

[62] Perales's study: Author's interview, Perales.

[63] From the stomach to the heart: I am indebted to Jim Boyce for the quotation and idea on which this title is based. Another term for this notion comes from a Slow Food meeting, where an anonymous wit once described the group's approach—saving biodiversity by appealing to food snobbery—as "Chez Panisse socialism."

[64] Chiapas cafés: Author's interview, Rosset. The chain of cafés is La Selva.

[65] Amaranth: Scaffidi, C., "Adriana Valcarcel," *Slow*, January 2002, n.p., available at: http://www.slowfood.com/Slowfood_UpLoad/Riviste/SLOW/EN/25/valcarcel.html (visited July 2002).

[66] Potatoes and salt: Kummer, C., *The Pleasures of Slow Food*, San Francisco: Chronicle Books, 2002 (forthcoming).

[67] Seed Savers Exchange: Information at http://www.seedsavers.org (visited June 2002),.

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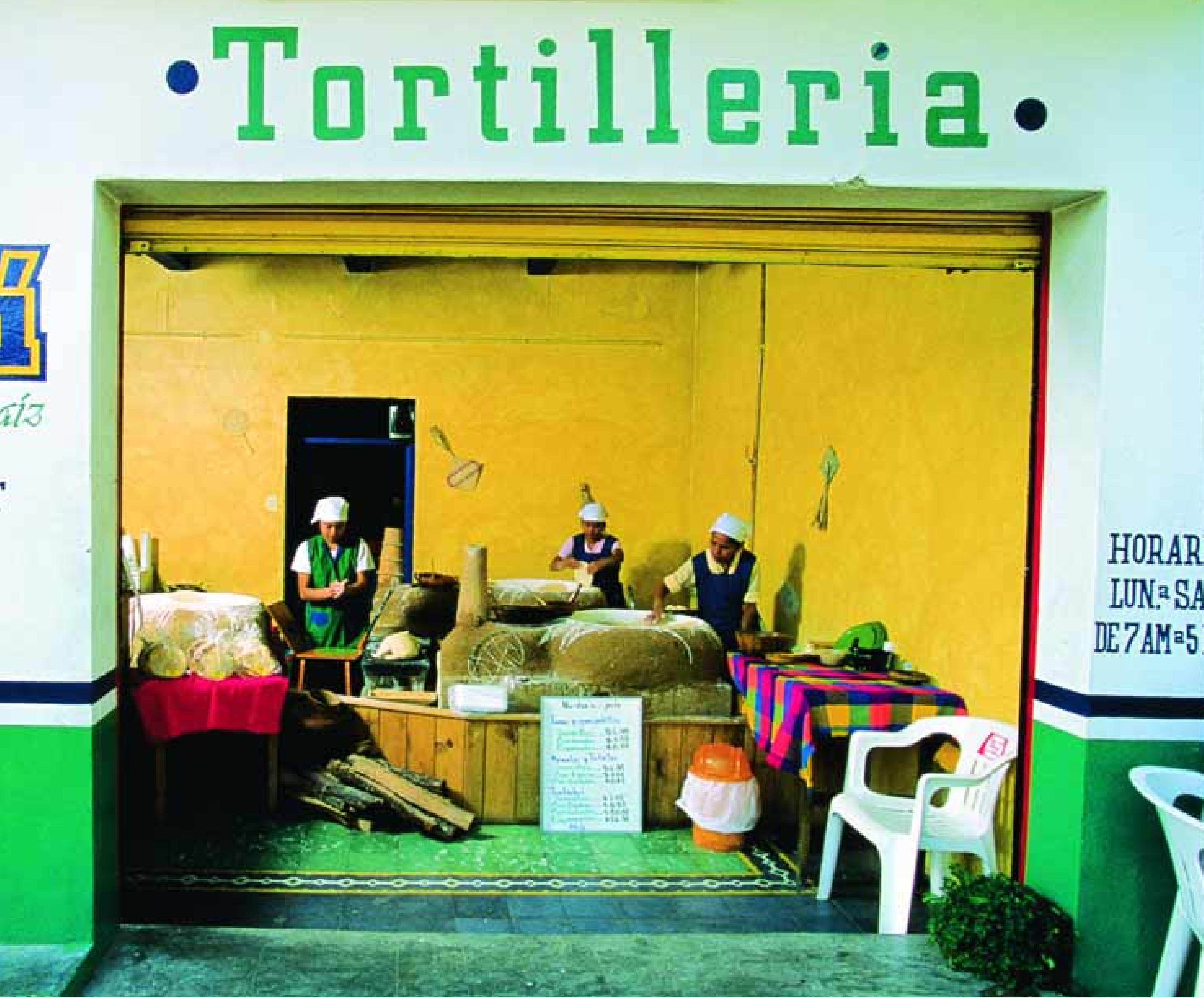
Tortillas are to Mexico what flaky-crusted bread is to France or short-grained rice is to Japan: a food that is an emblem of home.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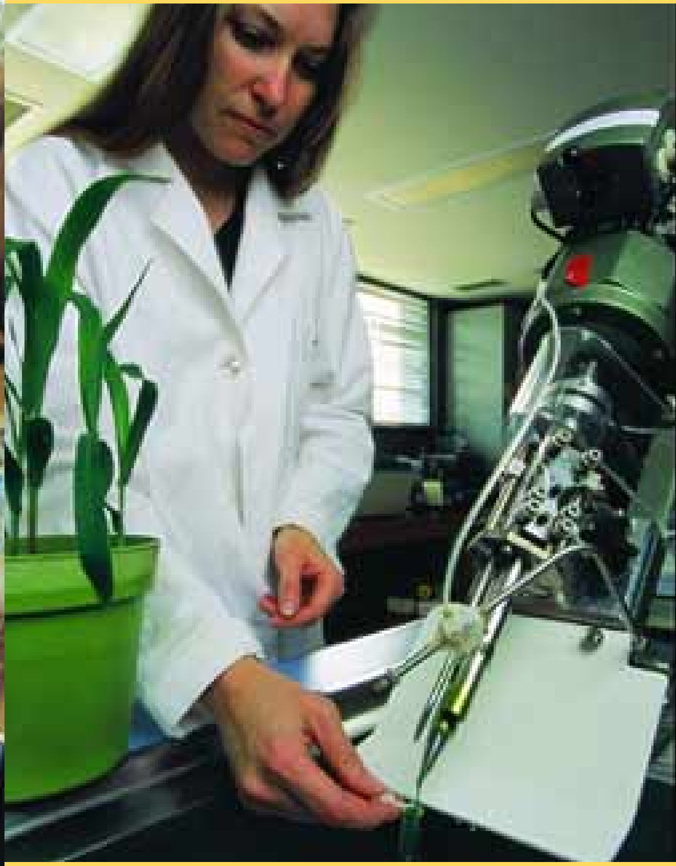
Left: making gourmet tortillas at Ítanoni; below: molecular biologist Marilyn Warburton extracts maize DNA at the CIMMYT genetics laboratory; inside left: Oaxaca smallholder Hector Diaz Castellano at the village granary where he stores his maize; inside right: Ítanoni tortilleria, where ancient maize is sold to a new, urban generation in Mexico.



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