Earth *Transformed*

William F. Ruddiman

occurred at least a few thousand years after the earliest human arrivals. Possible responses to this criticism counter that human populations took time to build to the levels needed to completely eliminate so many mammal species, or that the introduction of some kind of new hunting technology soon after human arrival may have been crucial.

The new arrivals from Asia were hunter-gatherers (and fishers) lacking bronze or iron tools. Yet several American cultures had begun to work copper by the time of European entry, and two of them (Aztecs in Mexico and Incas in Peru) had become massive empires. Also, as noted above, American peoples had become among the world's greatest agriculturalists (see Table 6-1). But because of geographic isolation (created by barriers of mountains and deserts) combined with very different climate zones and natural vegetation, many agricultural innovations remained localized, and agricultural patterns differed greatly from region to region.

Mesoamerica (Mexico and Central America)

Mesoamerica spans a range of climatic and vegetation zones (Figure 6-2, and see Figure 6-1). The region most relevant to the spread of agriculture includes the semi-arid central Mexican highlands, with dry tropical forests and runoff from mountain rains and snows, and wet tropical forests

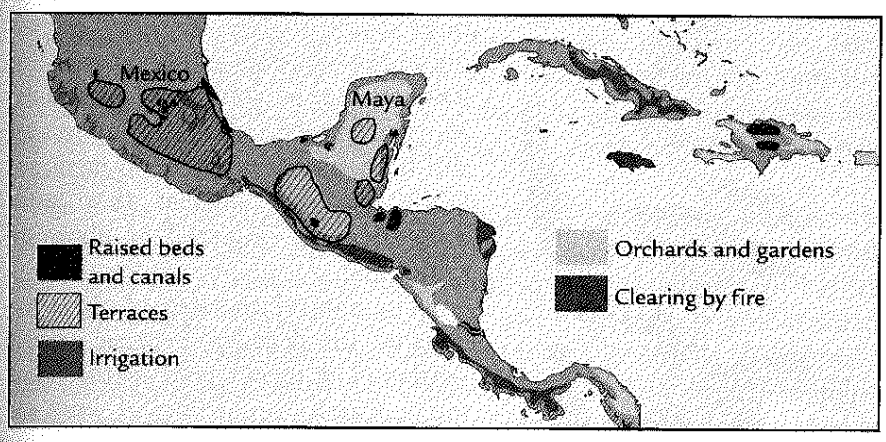

FIGURE 6-2 Centers of early agriculture in Central America. *[Adapted from map by C. C. Mann, W. Doolittle, and P. Dana, in C. C. Mann,* 1491 *(New York: Random House, 2006); courtesy of C. C. Mann.]*

FIGURE 6-3 Squash, domesticated in Central America. *[Robert L. Smith.]*

along the lowlands on the coasts of the Pacific Ocean and Gulf of Mexico. These regions were the center of domestication of an amazing variety of foods, including maize, squash, tomatoes, avocados, and several types of beans (Figures 6-3 and 6-4). The wild ancestors of tomatoes grew naturally in the areas now known as Peru and Ecuador as plants with tiny berries that were smaller than modern-day peas, but the slow domestication of these wild varieties to larger forms apparently occurred in what is now western Mexico.

The first agriculture in this region dates to 10,000 years ago or earlier, when several kinds of squash were first domesticated and grown in tropical lowlands. This date rivals the earliest agriculture in China and lags not far behind the earliest agriculture in the Fertile Crescent. By 8,700 years ago, evidence of early domestication of maize—one of the three major modern-day grain crops in the world—appears in the Central Balsas River valley in southwest present-day Mexico. Stone grinding tools of this age still have traces of maize on them, and DNA analyses suggest that initial domestication occurred at about the same time.

FIGURE 6-4 Beans, domesticated in Mexico. *[Robert L. Smith.]*

The natural ancestor of maize was debated for decades, because nothing similar to it grows wild in the region today. Careful archeological work and DNA analyses have shown that maize

FIGURE 6-5 Gradual domestication of a wild form of grass called teosinte (left) through intermediate forms over many thousands of years led to the modern crop maize (right). *[Courtesy of John Doebly.]*

comes from a natural wild grass calle **teosinte**, although the reason for its d mestication remains something of mystery. Wild wheat and rice have lar grains that look like their domesticate successors, but teosinte has a dozen so tiny "kernels" encased in a very ha outer casing (Figure 6-5). Why ear farmers found teosinte worth their a tention is difficult to understand. One interested in the sugar-rich stalks of haps they didn't actually pay much it as a minor supplement to other s may have chosen grains that had oper that didn't exhibit the shattering beha In any case, somehow, over many th farmers ended up selecting for larger,

As this process continued, maize of Mesoamericans for more than 4,0 of domestication had occurred by 8,7 too small to be relied on as a major to eat wild food sources along with not yet reached the point of provid that people needed.

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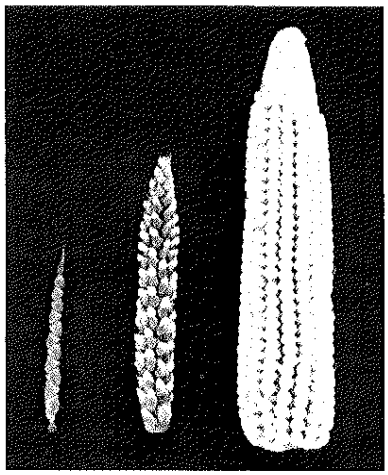

FIGURE 6-5 Gradual domestication of a wild form of grass called teosinte (left) through intermediate forms over many thousands of years led to the modern crop maize (right). *[Courtesy of John Doebly.]*

comes from a natural wild grass called **teosinte**, although the reason for its domestication remains something of a mystery. Wild wheat and rice have large grains that look like their domesticated successors, but teosinte has a dozen or so tiny "kernels" encased in a very hard outer casing (Figure 6-5). Why early farmers found teosinte worth their attention is difficult to understand. One possibility is that they were mainly interested in the sugar-rich stalks of the plant, not the kernels. Or perhaps they didn't actually pay much attention to teosinte at first, using it as a minor supplement to other sources of food. Instinctively, they may have chosen grains that had openings in the hard outer casings and that didn't exhibit the shattering behavior that made harvesting difficult. In any case, somehow, over many thousands of years, early American farmers ended up selecting for larger, juicier kernels.

As this process continued, maize remained a minor item in the diet of Mesoamericans for more than 4,000 years. Even though some degree of domestication had occurred by 8,700 years ago, the ears (cobs) were too small to be relied on as a major food source, and people continued to eat wild food sources along with crops like squash. Agriculture had not yet reached the point of providing the complete nutritional base that people needed.

By 4,300 years ago, ears of maize had become large enough for the crop to become sufficiently productive for greater, more widespread agricultural use. Combining maize with squash (domesticated earlier) and with beans, tomatoes, avocados, and melons (all domesticated later), people in what is now Central Mexico gradually developed a fully nutritional package of crops planted together in plots called **milpa**. Aside from its nutritional benefit, this combination of crops (particularly beans that can extract nitrogen from the air and store it in the soil) allowed land to remain fertile for relatively long periods of time. Eventually, maize and the other milpa crops spread south into the Amazon Basin and lower forests of the Andes and then north into

North America (Figure 6-6). Compared to Europe, however, the transition from a hunting and gathering life to a fully agricultural one was slow, in part because of the gradual pace of maize domestication, but also because wild animals suitable for domestication were not widely available for use in field labor.

In Mesoamerica, the success of milpa farming eventually made possible a sedentary life and the early emergence of several major civilizations based on agriculture (recall Figure 6-2). Between 3,500 and 2,500 years ago, the Olmec people on the Gulf Coast of Mexico formed one

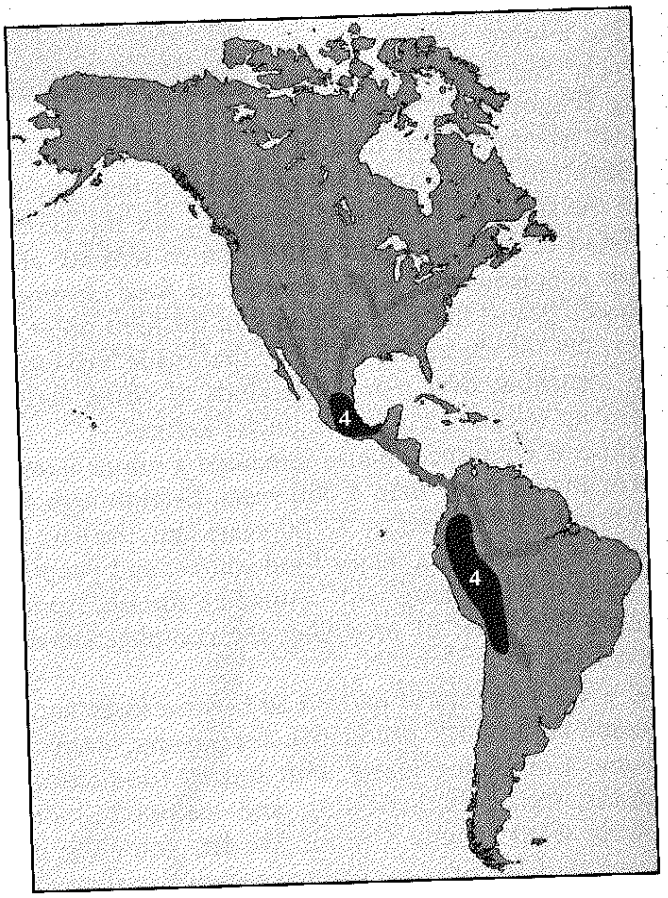

FIGURE 6-6 Dispersal of agriculture from centers in Mexico and the Andes. Numbers are thousands of years ago. *[Adapted from P. Bellwood,* First Farmers: The Origins of Agriculture *(Oxford: Blackwell, 2004); and from M. D. Purugganan and D. Q. Fuller, "The Nature of Selection During Plant Domestication,"* Nature *457 (2009): 843–848, doi:10.1038/nature07895.]*

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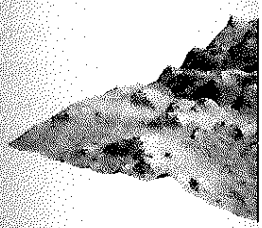

FIGURE 6-7 LIDAR-based reconstr
Caracol and nearby area. *[Courtesy o*

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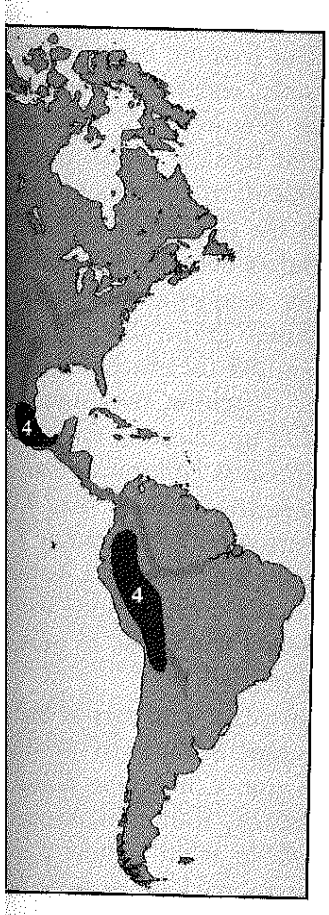

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the first technologically sophisticated American societies, with towns and cities, colossal stone statues, and a cultural influence that gradually spread to many other regions. Stalks of maize featured prominently in Olmec art. Between 3,000 and 2,000 years ago, a series of regional empires developed, including the Toltecs in the central northern highlands, and the Zapotecs followed by the Mixtecs in the southern highlands and along the Pacific coast.

On the Yucatan Peninsula farther south, Mayan cultures emerged between 4,000 and 3,000 years ago, as people began cutting the coastal forests to cultivate maize. Mayan farmers planted two crops a year by terracing higher terrain to direct runoff from rains, and by constructing raised fields in waterlogged terrain separated by submerged ditches and canals that supplied vegetation for use as fertilizer. An increase in Mayan populations in the frequently warring city-states caused heavy deforestation between 3,000 and 1,000 years ago.

The archeologist Arlen Chase and colleagues recently studied the large Mayan city of Caracol in the modern-day country of Belize, using LIDAR (*Li*ght *D*etection *A*nd *R*anging), a technology that can peer through the jungle canopies and reveal structures lying below them (Figure 6-7). Previously, twenty-five years of painstaking ground-based archeological fieldwork at this site had identified several major buildings, connecting roads, and terraced areas. In just four days, this new LIDAR survey thoroughly mapped an area more than seven times larger, down to the scale of features such as small buildings, causeways, and very extensive agricultural terraces. Future use of this technique may bring many more such revelations about other tropical rain forest areas. Based on this LIDAR survey, we know that at its peak, between the years 500 and 900, Caracol had a population of more than 100,000 people, with all the land for miles around in use, mainly for agriculture. Caracol was

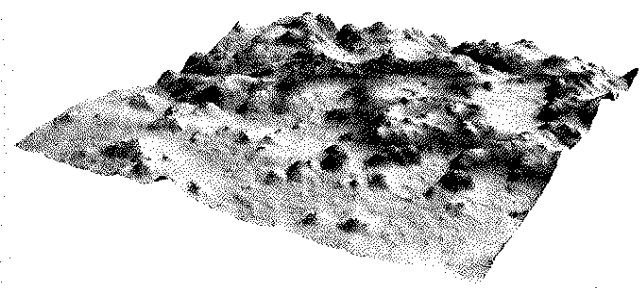

FIGURE 6-7 LIDAR-based reconstruction of Central American Mayan city of Caracol and nearby area. *[Courtesy of Arlen and Diane Chase, Caracol Archeological Project.]*

FIGURE 6-8 Artistic reconstruction of Tenochtitlan at the site of present-day Mexico City. *[Courtesy of Tomás Filsinger.]*

but one of dozens of cities packed into this densely inhabited region. Sometime between the years 800 and 1000, the classic Mayan cultures collapsed because of some combination of droughts, environmental degradation, resource depletion, and strife among different groups.

Northeast of present-day Mexico City, a powerful culture centered on the city of Teotihuacan appeared 2,000 years ago. At the height of its power between 400 and 600, Teotihuacan boasted the third-largest stone structure in the world, the Pyramid of the Sun. Teotihuacan fell in the 700s.

By the time of European arrival, the region was under the control of an alliance of city-states headed by the Aztecs. Their capital city of Tenochtitlan was a complex of artificial islands and intervening canals that had been constructed in Lake Texcoco at the site of present-day Mexico City (Figure 6-8). Tenochtitlan was bigger than most European cities, with fresh water brought in from nearby springs, thriving wetland agriculture, and streets swept clean every night.

In summary, land clearance for agriculture was already widespread by 4,000 to 3,000 years ago in Mesoamerica because of early crop domestication. As clearance continued in most regions during subsequent millennia, and maize was domesticated, major cultures prospered. At the eve of European conquest, some fifteen million people were living in Mesoamerica. The forest clearance needed to cultivate enough land to feed fifteen million people would have emitted a substantial amount of CO_2 to the atmosphere during the interval when atmospheric CO_2 concentrations were rising (recall Chapter 3, Figure 3-7).

The Andes

The second area in the Americas with a long history of early agricultural innovation spans diverse environments in western South America—from the hyper-arid Pacific coast, across the heights of the Andes, and eastward to the warm, humid low (Figure 6-9).

Local forms of squash and bean years ago in the northern Andes technologically sophisticated culture years ago at an urban center called of modern-day Lima. Because the no rain, it seems an unlikely place support an advanced civilization, bu of fish and shellfish, and the native and vegetables by diverting water Andes into terraces piled with soil.

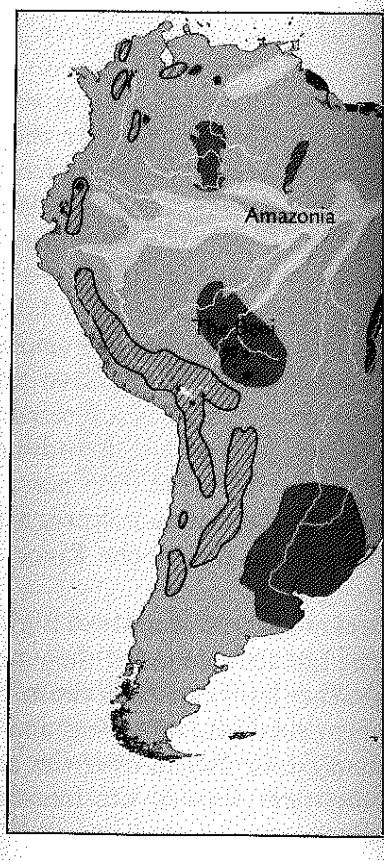

FIGURE 6-9 Centers of early agriculture *C. C. Mann, W. Doolittle, and P. Dana, in C. C. M courtesy of C. C. Mann.]*