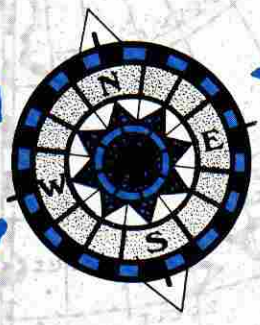
The COLUMBIAN ENCOUNTER and Land-Use Change



Last June, representatives from countries around the world assembled in Rio de Janeiro, Brazil, at the United Nations Conference on Environment and Development (UNCED). The establishment of UNCED and the attention surrounding it attest to humankind's recognition that people have transformed and continue to transform the Earth with serious implications for the physical well-being of the planet and its inhabitants. This coming 12 October marks a significant event in humankind's history of global change: the passing of 500 years since Cristobal Colón, or Christopher Columbus, anchored his three small Spanish ships off the shores of the Bahamas and opened the door to transcontinental contacts among all of the inhabitants of the world.

The two events, though separated by half a millennium, are not unrelated. The 1492 "Columbian encounter" set in motion the most dramatic changes in land use and land cover induced by human action up to that time. Within 250 years, virtually all land uses, land covers, and biota in Mexico, Central America, the Caribbean, and South America had been affected in some way by the encounter, in many cases dramatically.[1] The scale and pace of environmental change associated with the encounter foreshadowed similar changes associated with the colonization of other countries by Europeans during the 16th and 17th centuries and with the escalation of human impacts following the Industrial Revolution. Therefore, 1492 is a watermark not only for the emergence of the modern world but also for the beginning of the global change that UNCED addressed or, at least, that component of it related to land-use and land-cover change.

Because UNCED focused mainly on the state of current environmental change, its implications, and the actions needed to address the change, it is understandable why past events,

B. L. TURNER II is a professor of geography and director of the George Perkins Marsh Institute at Clark University in Worcestor, Massachusetts. **KARL W. BUTZER** is the R. C. Dickson Centennial Professor of Liberal Arts in the department of geography at the University of Texas at Austin.

BIAN
'ER

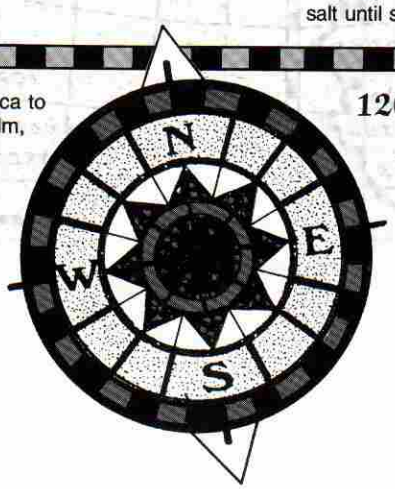
By B. L. Turner II
and Karl W. Butzer

such as the Columbian encounter, were not much considered.[2] It is less understandable, however, why the greater community of scholars and researchers concerned with human-induced environmental change has not given much thought to the association between past and present change.[3] After all, contemporary global environmental change consists of two broad types—systemic and cumulative. Systemic change operates directly on the biogeochemical flows that sustain the biosphere and, depending on its magnitude, can lead to global change, just as fossil-fuel consumption increases the concentration of atmospheric carbon dioxide. Systemic change is largely associated with, but not limited to, the Industrial Age and thus has

1200s The Mexica (who became the Aztecs) enter the basin of Mexico (the area surrounding present-day Mexico City) as migrants and remain as serfs. By this time, the Classic Period cultures of Mesoamerica had collapsed some 200 to 400 years earlier.

1200s Maya along the north coast of the Yucatán Peninsula dominate salt production and long distance trade in salt until shortly after the Spanish conquest.

1200s Arawaks move from South America to populate all of the Caribbean realm, including the Bahamas.



1200s Abandonment by the Anazazi people of most of the large pueblos in the Four Corners region of the North American southwest (present-day New Mexico, Arizona, Colorado, and Utah) is completed by the late 1200s.

grown especially important over the more recent past.

Cumulative change, on the other hand, has been the most common kind of human-induced environmental change since antiquity and was dramatically exemplified in the Columbian encounter.[4] Cumulative changes are geographically limited but, if repeated sufficiently, become global in magnitude.[5] Changes in the landscape, such as changes in forest cover, cropland, grasslands, wetlands, or human settlements are an example of cumulative change. Some cumulative changes reached continental, even global, proportions long before the 20th century,[6] including deforestation, the transfer of plants and animals between continents, modification of grasslands, and, possibly, the extinction of a large number of animal species in the Quaternary period.[7]

In contrast to UNCED's interest in contemporary global change, research relevant to the Columbian encounter has a significant environmental heritage and has flirted with associations between past and present global change.[8] Such recognition, however, has been overshadowed by the contentiousness and polarization surrounding what some people see as a quincentennial celebration of European authority and superiority and a lack of attention to alternative viewpoints of the meaning of the events of 1492. The quincentenary celebration has become, like UNCED, a forum for a multitude of interest groups who demand consultation, consideration, and influence in setting policy and interpreting history.[9]

Tensions among the various groups have affected interpretations of the environmental consequences of the Columbian encounter and have resulted in the creation of two recurrent myths.[10] In the first, Native American Indians, or Amerindians, are depicted as stewards of the land who operate under an ethos of harmony with nature, employ environmentally sensitive and sustainable agricultural practices—most notably swidden or slash-and-burn horticulture—and minimally change the wilderness of the Americas. In the second, often complementary, myth, colonial-period Europeans are shown to seek to control and exploit nature and to employ agricultural practices, in both Europe and the Americas, that are far less sustainable and usually degrading to the environment and lead to large-scale deforestation, destruction of croplands, and deterioration of grasslands.[11]

The antecedents of these interpretations can be traced back to Columbus himself, who described the island of Hispaniola (now divided into Haiti and the Dominican Republic) as a terrestrial paradise.[12] The modern taproot of these myths, however, is the depiction by 19th-century Romantic and primitivist artists of America as a pristine wilderness, an image that was carried almost uncritically into the second half of this century.[13] More recent roots stem from sources perceived to be outside the mainstream: Amerindians seeking to rectify misperceptions of their heritage and cultures, environmentalists seeking alternatives to a mass-consumption society and high-input agriculture, and "critical theorists" who consider the seeds of most environmental damage to have been sown by Western culture and capitalism.

Regardless of their sources, the two myths—Amerindians as nature's stewards and Europeans as its destroyers—and their implications for environmental change simply do not withstand scrutiny. They do not represent the views of the professionals steeped in the understanding of nature–society relationships and active in research on land-use and land-cover changes in pre- and post-conquest Latin America. Much information exists about the state of European and Amerindian landscapes at these times and about the changes in both wrought by the Columbian encounter.[14] Little, if any, of this work, however, has been linked directly to contemporary environmental change, global or otherwise.[15]

On the Eve of the Encounter

The Columbian encounter was not the first time Europeans landed in the Americas. But, unlike the Viking landings, which occurred approximately 500 years before, the Columbian encounter occurred at a moment when Europe was ready and able to take advantage of the "New World." By the late 15th century, the budding nation states of Europe had developed the technological capacity for long-distance, transoceanic commerce and were beginning an intense competition with each other for the resources and wealth expected from trade with the Orient. The Portuguese, in fact,

1200–1500 During this period, the development of the Mississippian mound-building traditions reaches a peak in southeast North America.

1250 The Inca establish Cuzco, Peru, as their capital.

1271–95 Marco Polo travels east to Asia to expand European trade horizons.

1238–48 Christians reconquer Valencia, Cordoba, and Sevilla, Spain, from Muslims.

1250 Cahokia (east of modern St. Louis, Missouri), perhaps the largest Amerindian settlement and containing the largest stepped pyramid north of Mexico, begins to dissipate.

had just found a passage around Africa's Cape of Good Hope and were poised to break the Islamic domination of that trade by sailing into the Indian Ocean.

Land Use in Europe

The seafaring explorations that began in the 15th century were largely driven by a new exuberance for economic and political expansion and by population growth problems. It is important to understand that, from about 1350 until 1500, Western Europe witnessed an overall population decline and that the peak population of the early 1300s was not reached again until the late 1500s.[16] Hence, the initial stages of Europe's "age of exploration" occurred at a time of population stagnation or loss, and the early Spanish colonization of the Americas occurred during a time of renewed population growth in Western Europe and a revival of agricultural systems. Only during the late 1500s was land stress apparent in various parts of Western Europe.[17]

Large-scale land-cover changes had taken place in Europe over the past centuries, including the deforestation of more than 100,000 square kilometers, the drainage of wetlands, and the continent-wide modification of biota.[18] Such changes were necessary to sustain long-term occupation by a growing population and were apparently comparable to changes induced by other societies and cultures with similar needs. For example, only minimal differences in the scale of deforestation and landscape changes were found between feudal Europe and imperial China, though the cultures of each area supposedly operated under different views of nature–society relationships—mastery over, versus harmony with, nature.[19] Although managerial mistakes were made, overall it is difficult to single out European cultures as especially destructive to their environments when population size, technological capacity, and standards of living are taken into account.

The basic food production system in southern and central Spain in the late 15th century is a case in point. This system, which was similar to others of the western Mediterranean region, had been developed through the transformation of the natural woodland into a mosaic of agricultural and sylvipastoral land uses and was based on native and introduced plants adapted to the seasonal rhythm of summer drought and winter rains. The agricultural system involved a mix of cereal cultivation, olive groves, and vineyards; the planting of legumes or the use of fallowing to restore fertility during a two-course crop rotation; and the seasonal grazing of livestock on stubble. Except for some local use of marginal soils and topography for swidden agriculture, the sylvipastoral system was carefully managed by varying livestock mobility to avoid overgrazing and allow native legumes to maintain reservoirs of organic matter, nitrogen, and phosphorus in the soil. In some regions of the Iberian Peninsula, this mosaic of dry farming and controlled grazing was complemented by an often sophisticated irrigation system for orchard gardens or exotic commercial crops.[20]

Therefore, the systems of the western Mediterranean countries, far from being environmentally destructive, tended to involve careful modifications and transformations of the local environments. Of course, the landscape was significantly altered, even in areas of marginal cultivation, and the Little Ice Age (A.D. 1560 to 1890) caused a series of land-use adjustments throughout Europe, as did the overall growth in population.[21] Yet, there is little evidence that the Columbian encounter was primarily stimulated by excessive land-use pressures or land degradation in the western Mediterranean region or in Europe in general.

Land Use in the Americas

On the eve of the landing by Columbus, North and South America contained a wide range of land types, from less disturbed wilderness to totally transformed landscapes. As in Europe, the degree of change on these landscapes was related to the length of human occupation and the level of environmental pressure as a result of population size and political and economic conditions. Unlike Europe, however, many of the more heavily occupied lands in the Americas were located in the tropics and, therefore, offered different environmental opportunities and constraints to the inhabitants.

Probably about 54 million Amerindians lived in the Western Hemisphere in 1492 (see Table 1 on page 20). They were dispersed throughout a wide range of social and political structures, from small, kin-based groups to elaborate state organizations extending over very large areas, and were engaged in trade within and without their domains.[22] Large populations and high levels of state development overlapped in central Mexico, in the highlands of

1400–1519 A large-scale "chinampa" system, similar to the polders in the Netherlands, is established and maintained in the southern region of the basin of Mexico. The system uses dikes to separate freshwater from saltwater.

1434 The Triple Alliance of city-states (Tenochtitlán, Texcoco, and Tlacopan) in the basin of Mexico is formed, giving rise to the Aztec empire that would control more othan 200,000 square kilometers and 10 million people by 1500.

1325–45 Tenochtitlán, the Aztec capital, and its sister city, Tlateloco, are established on islands in the southern part of Lake Texcoco in the basin of Mexico. By the time of European contact, 150,000 to 200,000 people inhabit Tenochtitlán, and its metropolitan area contains some 400,000 inhabitants.

1402–96 Spain conquers the Canary Islands, which lie 1,280 kilometers southwest of Spain.

Central America from Chiapas, Mexico, to northern Costa Rica, and throughout the Andean realm. Substantial populations also were present on some of the Caribbean islands, in various parts of coastal Mexico and Central America, in lowland South America, and in the eastern woodlands (including the Mississippi River delta), the northwestern coast, and the southwestern region of North America.[23]

In these and other areas, the Amerindians employed a variety of agricultural techniques: mountain slopes reconfigured into flanks of often irrigated terraces; gentle terrain sculptured into mosaics of open fields aligned with earthen planting mounds and ridges, gardens, and orchards; and wetlands reshaped into raised and drained fields.[24] Even where occupation was less frequent, considerable modification of environments took place through such activities as agroforestry.

Although terracing was used throughout the Americas, this form of slope transformation was most prevalent in the area extending from the North American Southwest to the highlands of Guatemala and throughout the central Andes Mountains.[25] From southwestern North America to Central America, Amerindians converted intermittent drainage channels to cultivated land through the use of weirs and check dams.[26] The use of nonirrigated, sloping terraces was prevalent throughout highland Mesoamerica (the region consisting of present-day Mexico and Central America), while slopes in the Andes Mountains had been reconfigured through the use of level, irrigated terraces.[27]

Open-field, rain-fed agriculture was commonly employed on gently sloping terrain and typically involved significant surface modifications in the construction of earthen mounds or ridges. These labor-intensive features served multiple functions, depending on the environment and crops in use, and, once constructed, increased the value of land.[28] Also, the use of mounds and ridges suggest a land-intensive cultivation system based more on sustained field inputs than on the constant shifting of crop sites.[29] The construction of mounds on well-drained fields was prevalent for potato production at the high altitudes of the Andes, for manioc production in tropical locales—especially northern South America and the Arawak Antilles of Hispaniola—and for maize cultivation throughout Mesoamerica and the eastern woodlands of North America.

Amerindians used irrigation to expand or intensify cultivation on lands otherwise constrained by insufficient water supplies. Large-scale canal irrigation was used in the Andean–Pacific lowland region of South America and in certain places in the North American Southwest, some of which involved spectacular engineering feats.[30] Elsewhere, especially from Mesoamerica into the North American Southwest, the use of run-off irrigation was particularly important.[31] Regardless of the source of water, private gardens, orchard gardens, and orchards were commonly irrigated, particularly orchards used for trade crops such as cacao in Mesoamerica and, perhaps, in the lowlands of northern South America.[32]

Amerindians were particularly skilled in the art of wetland agriculture, from seasonal cultivation of the desiccating edges of wetlands to complete transformation of seasonal wetlands and shallow lakes.[33] Interestingly, the most extensive use of wetlands may have occurred long before the Columbian encounter, but the most impressive wetlands agriculture system known, the *chinampas* of the basin of Mexico (the area surrounding present-day Mexico City), was in full use in 1492.[34] This system was based on the reconfiguration of the location of water within shallow lakes and marshes, without drainage, and the addition of large, artificial garden beds.[35] Use of wetlands for agriculture did not always involve the *chinampa* system. Almost invariably, wetland cultivation involved the digging of ditches or canals and, commonly, some form of field raising among the ditches. In the basin, the *chinampa* system was integrated with dikes and sluices to protect freshwater from mixing with saline water and to allow for multiple crop production. Although

(continued on page 37)

TABLE 1
AMERINDIAN POPULATIONS CIRCA 1492

Region	Population
North America	3,790,000
Mexico	17,174,000
Central America	5,625,000
Caribbean	3,000,000
Andes Mountains	15,696,000
Lowland South America	8,619,000
Total	**53,904,000**

SOURCE: W. M. Denevan, *The Native Population of the Americas in 1492*, 2d ed. (Madison, Wis.: University of Wisconsin Press, 1992).

1445–61 Portuguese explorers reach the Cape Verde Islands and Guinea by 1461 and begin the Atlantic slave trade.

1450–1525 The Inca empire extends from northern Ecuador to central Chile and is linked by 30,000 kilometers of paved roads.

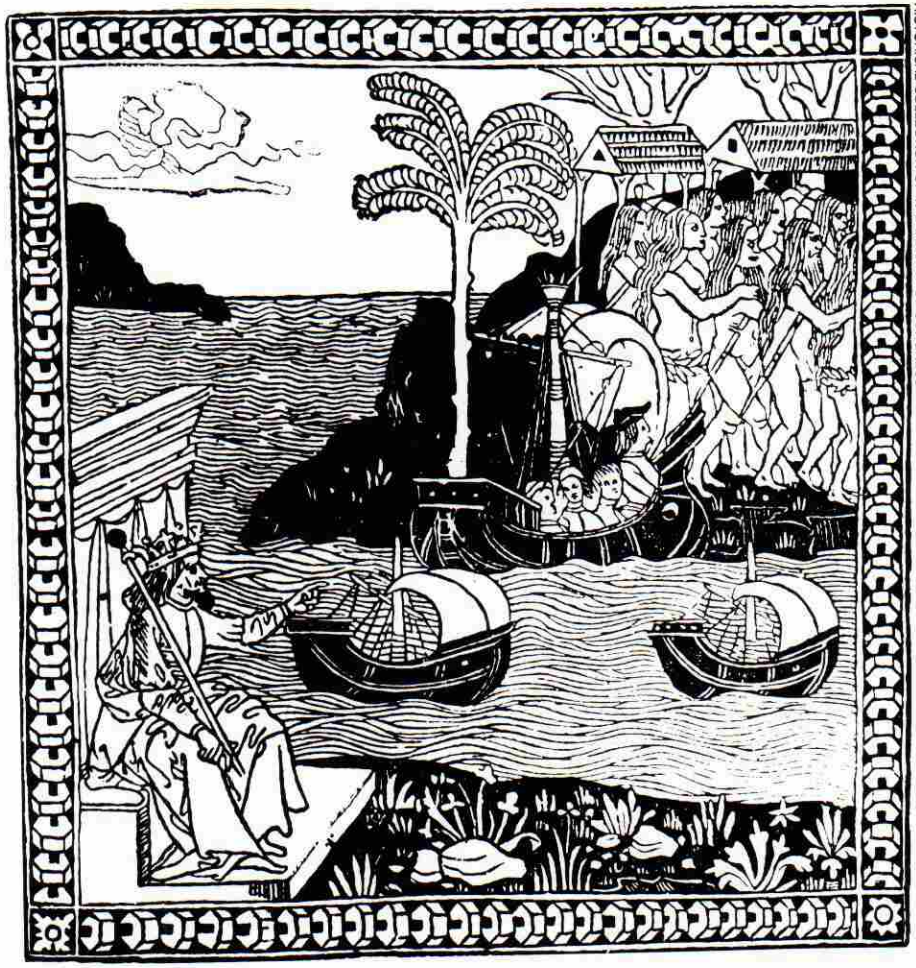
1470–80 The international banking system links Florence, Italy, Augsburg, Germany, and Bruges, Belgium, and lays the groundwork for modern commercial banking systems.

1488 Bartholomeu Dias reaches the Cape of Good Hope in Africa.

1490–1600 Europe experiences significant population growth during this period.

The Columbian Encounter

(continued from page 20)

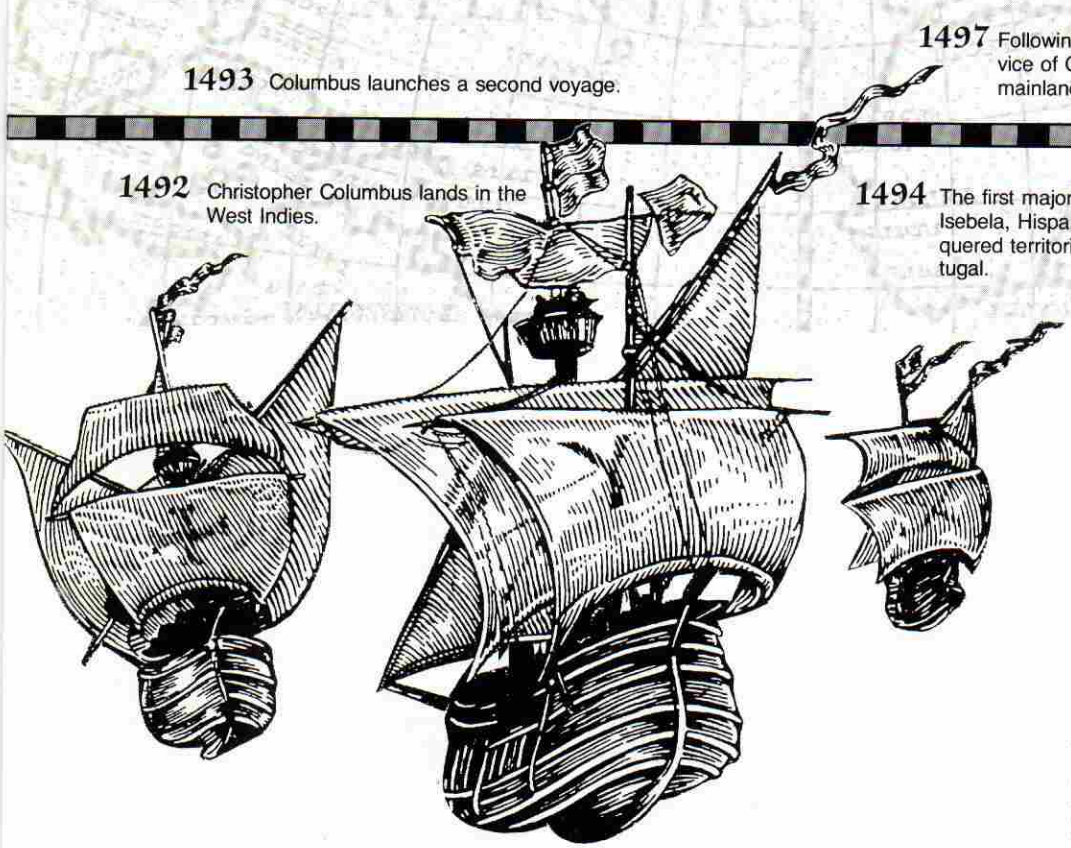


HISTORICAL COLLECTION OF THE LIBRARY OF CONGRESS

at different times, a considerable proportion of the wetlands in the Americas was modified for cultivation, including wetlands in the Andes, the lowlands of South America, Mesoamerica, and the Mississippi River basin as far north as present-day Wisconsin.[36] As with terracing, no estimate of the total area of Amerindian wetland cultivation has been developed. However, 500,000 hectares of ancient wetlands fields, for example, have been located in the San Jorge River basin of Colombia.

Landscape modification also occurred in more sparsely occupied areas, particularly through the Amerindians' use of fire. For instance, Amerindians expanded, or at least maintained, grasslands in the plains of North America by burning them while on a hunt.[37] Similarly, burning grasslands for agriculture in Central America and portions of South America may have been responsible for the extended patchworks of grasslands and the extended distribution of pine trees into some tropical forest lands.[38] In large part, the forests of the Americas, from Canada to Argentina, were so highly disturbed or modified by Amerindian use by 1492 that it is surprising that even the popular literature has missed this point.[39] The evidence of ancient human occupation throughout the Amazon River basin, for example, is sufficient to warrant the speculation that the tropical forests existing at the time of the encounter (and, possibly, today) had been significantly influenced by human use, an observation that also can be extended into regions of Central America and the humid lowlands of Mexico.[40] This disturbance stemmed from swidden, or shifting, cultivation and permanent cultivation and from forest culling and other activities involved in agroforestry.[41] The degree to which swidden agriculture in the Americas shifted is a matter of speculation. Stone tools, even with the assistance of fire, are not an efficient means of clearing forest lands; the extensiveness of swidden agriculture may have awaited the introduction of steel tools by Europeans. In the Yucatán Peninsula, for example, orderly settlements were surrounded by orchard gardens and short-term fallow open fields, which were separated from the next village by forests containing economic species that were probably the product of Amerindian selection and protection. Indeed, the composition of these forests, many long abandoned by the time of the Columbian encounter, reflected past land-use activities, relics of orchards and agroforestry systems, and overgrowth on the remains of ancient cities, towns, and villages.[42]

In New England, old forests prior



to European settlement were repeatedly modified by fires, hurricanes, and selective diseases. Initial farming by Europeans was small scale and of low intensity, with little discernible impact on vegetation until the advent of forest clearcutting and agricultural expansion in the late 1700s. Increased abandonment of farms and population nucleation in towns allowed the forests to regenerate after 1850, but today's New England woodland is dominated by white pine rather than by the previous species—hemlock, beech, and chestnut—and reflects differential colonization rates, disease, and fire control.[43] In other words, contemporary "protected" forests developed differently than did prehistoric "natural" forests, although both were modified by periodic catastrophes. Such insights are important to develop forest management and conservation strategies.

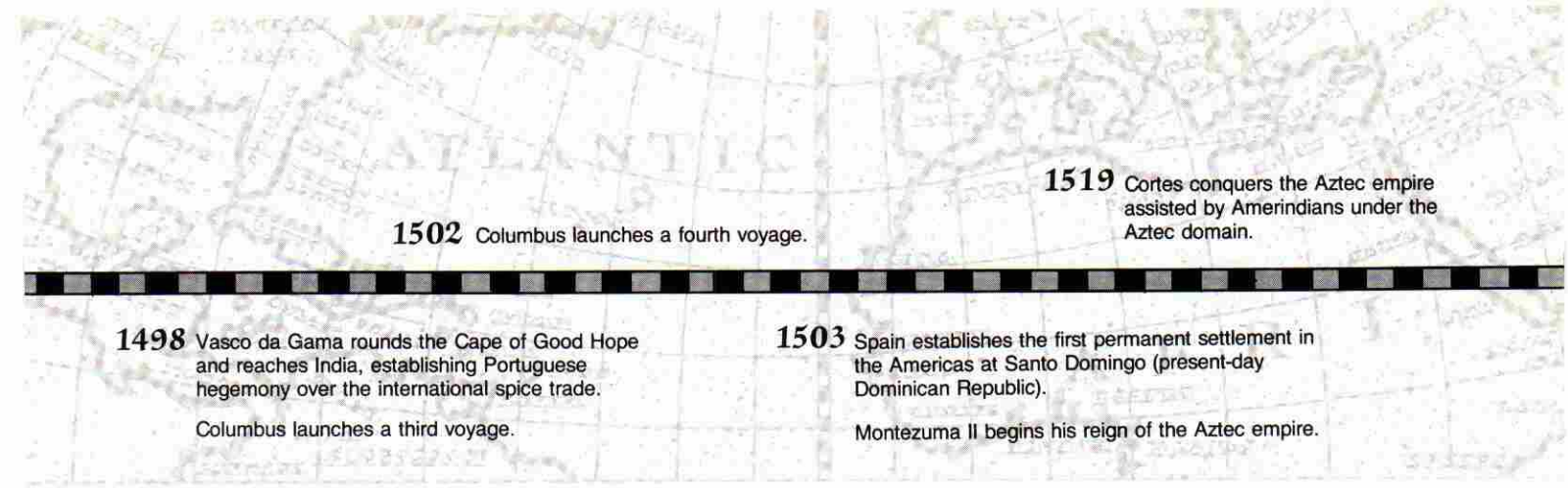
The evidence is clear. Although it is not understood how vegetation would mature without human intervention, pre-Columbian Amerindians used a wide variety of agricultural systems, not simply swidden agriculture, and, in pursuit of these systems and other needs, they made extensive land-cover changes in the Americas. Palynological data demonstrate the magnitude of deforestation and other complex changes in land cover over time. Although many pre-Columbian agricultural landscapes were successful and sustained long-term occupation and societal growth, some were created and abandoned, while others were occupied at length and degraded. Furthermore, agro-engineering mistakes, such as inoperative canal irrigation, inhibited the use of some arid areas, and sustained intensive land use often led to soil loss and degradation and contributed to chronic famine.[44]

Some Impacts of the Encounter

In the first century and a half after the Columbian encounter, which largely involved the inhabitants of the Hispanic Americas, a number of socioeconomic events occurred that had immediate and long-term impacts of substantial significance for global environmental change.[45] Among these events were the plundering of the mineral wealth of the Americas and the destruction of the large Amerindian populations.

As estimated $6.1 billion (in 1988 dollars) in precious metals were taken from the Americas to Europe during the first 150 years after the encounter.[46] This wealth, immense for its time, not only helped to propel the reordering of land use and land cover worldwide through European colonization but also helped to bankroll the development of the subsequent Industrial Revolution and, by extension, the initial stages of contemporary systemic global environmental change.[47]

The destruction of Amerindian populations changed the character of land occupancy in the Americas and ultimately created the "wilderness" awaiting the arrival of the late European settlers. The pace and magnitude of the depopulation of the Amerindian peoples remain unprecedented in annals of demographic history: An estimated 76 percent of the population of the Americas south of the present-day United States was eliminated between 1492 and 1650.[48] By the time sufficient and relatively reliable censuses were undertaken in the Americas, Amerindian populations had been greatly reduced. Reconstructions of large Amerindian populations at the time of the encounter, therefore, were challenged because very little evidence existed of such large depopulations elsewhere, including the pandemics of medieval Europe. Models drawing on conservative mortality figures and other evidence indicate that the massive depopulation was highly possible.[49] This catastrophe resulted from a number of factors, in-



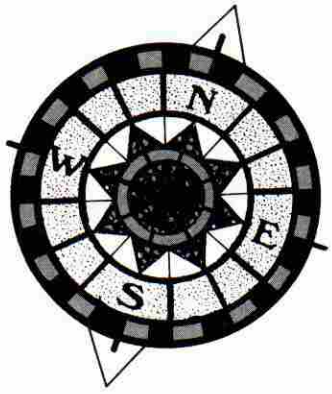
cluding the Europeans' harsh treatment of Amerindians. However, none was so devastating as the introduction of diseases from Europe.[50] Because they were isolated from the rest of the world, the Amerindians had little resistance to such exotic diseases as smallpox, measles, and typhus, and the staggering population losses that occurred triggered a number of systemic feedback impacts that further reduced the population.

Land-Use Changes in the Americas

The scale of depopulation in the Americas far exceeded the number of Europeans settling there in the 16th century. One hundred years after the encounter, in fact, only 175,000 Spaniards had colonized the Americas in the wake of the precipitous decline in the Amerindian population.[51] A significant drop in land use, therefore, left many former Amerindian agricultural lands empty because the remaining population could not maintain them, particularly lands formerly sustained by labor-intensive systems. Land abandonment was particularly acute in the tropical lowlands, and forced resettlement of the remaining Amerindian populations affected occupancy in most locales throughout the Spanish-held territory. The overall effect was not only a loss of productive agriculture and a diminishment of cultivation in general but also the afforestation of many tropical lowlands. Regions of the lower gulf coast of Mexico, the southern parts of the Yucatán Peninsula, lower Panama, and the eastern slopes of the Andes, among others, have retained the humanly modified, regrowth forests into modern times, though most of the regions are currently under heavy use. Sustained post-Columbian afforestation was not echoed in North America, however. Amerindian depopulation in the eastern woodlands was initially not as severe as that in Latin America, and, from the outset, European colonization in North America focused on further clearance of the forest for agriculture. Afforestation of the eastern woodlands did not begin until the 19th and 20th centuries, when changing economies rendered agriculture less competitive.[52]

Occupation of the Americas after European settlement differed in several ways from that before 1492. Although the initial Castilian settlers, for instance, preferred the cooler and relatively dry intermontane basins of the tropical Americas and the arid coastal lowlands of Peru, the Spanish eventually moved into the highland environments because they were somewhat similar to regions of the Iberian Peninsula, were amenable to Spanish agricultural technologies and biota, and, in a few cases, had existing infrastructures on which the Spanish could build, such as Amerindian irrigation systems. In short, the highlands offered land that was not only environmentally preferable but also more suitable for the Iberian agrosystem than were the tropical lowlands.[53]

Because their agrosystem was based on the production of winter wheat, however, the Spaniards were prohibited from following this system, except in certain coastal areas in higher latitudes, such as in central Chile, because the tropical highlands of the Americas receive mostly summer, not winter, rains, as in the Mediterranean region.[54] Thus, the Spanish were forced to develop a different system of winter wheat cultivation based on irrigation and to place a premium on lands that contained existing Amerindian irrigation systems or on those where such an infrastructure could be developed.[55] Furthermore, the use of plows and draft animals, unknown to the pre-Columbian Americans, permitted irrigation on minimally sloped lands where plowing could be used most efficiently.



These changes in the rudiments of the system of cultivation in the highlands had two broad implications for land use and land cover. First, the changes concentrated settlement in the highlands and, thus, reduced the relative importance of the occupation of the tropical lowlands. Secondly, use of the plow allowed vast areas to be cultivated in the highlands with a small labor force and, along with irrigation of winter wheat crops, shifted the balance of cultivated lands to the well-drained soils of highland valleys and basins. This shift stood in contrast to the Amerindians' use of high slopes and bottom wetlands, which did not handicap their less discriminating horticultural tools. Furthermore, Spanish preference for highlands favored the drainage of valley bottom wetlands and contributed to the demise of many wetland agricultural systems.[56]

1520–21 Smallpox, imported from Europe, breaks out on the mainland of the New World.

1525 Gonzales Fernández de Oviedo writes the first natural history of the Caribbean, including parts of Mexico and the Americas.

1519–22 Ferdinand Magellan circumnavigates the Earth.

1521 The breeding of cattle, sheep, and goats begins in Mexico.

1525 Cortes encounters vast tracts of sparsely inhabited tropical forest in Petén (modern Guatemala) that, some 700 years previously, had been largely opened and densely settled by the Maya.

Of the new biota brought to the Americas, none had such an immediate impact on land use and land cover as did domesticated animals, of which the Amerindian had few. Large herd and draft animals—cattle, sheep, goats, horses, mules, and oxen—were particularly instrumental to early land use by the Spanish, including livestock production, which was oriented to trade in leather, wool, and cured hams. Also, use of the horse spread rapidly northward from Mexico and was adopted by the inhabitants of the North American Great Plains and altered their economy for several hundred years before the invasion of the Europeans.[57]

The production of livestock, especially cattle and sheep, and the proliferation of semiferal animal populations, had large-scale, dramatic effects on land use and land cover throughout the Americas, including the Caribbean islands, Mexico, Colombia, and the pampas of Argentina.[58] Hispaniola, the first land mass in the Americas to be occupied by Europeans, was devastated by the rapid and complete destruction of the native population and by the explosion of the cattle, hog, and horse populations, much of which ran wild. By the later 1500s, lands were severely overgrazed, and gully erosion from trampling by livestock was considerable.[59]

But Hispaniola may have been an extreme case; only a modest expansion of open habitats can be inferred for the gulf coast of Mexico because high-cellulose, "old" grasses were burned to improve livestock grazing in the tropical lowlands. Interestingly, some of the deforestation that may have been involved with the use of tropical lowlands for livestock production probably involved lands that were formerly cultivated by Amerindians calling into question how much, if any, old forest was cut to support livestock population.[60]

Livestock production, of course, was the pastoral complement to wheat production among the Spaniards in the highlands. Initially, the uncontrolled cattle grazing wreaked havoc on agriculture because of the large numbers involved, and it may have led to the deteriorating of pastures in Mexico.[61] However, the Spaniards brought this free-range production system under strict control by the 1550s by moving cattle production from central Mexico to the gulf coast and northward to the Bajío and beyond. Herds of sheep much larger than those of cattle were managed by seasonal migration of 250 kilometers or more by the 1580s and up to 800 kilometers by the 1640s. This mobility reduced pressures on dry season pasture, similar to livestock management in Spain, and explains the lack of evidence for soil erosion as a consequence of degraded soil cover until the late 18th century, despite the intrusive biomass of some six to eight million sheep.[62]

Another biotic exchange that had consequences for land cover was the introduction of weeds and other noneconomic plant species. A myriad of weeds were exchanged between the Americas and Europe, both intentionally and not, and the introduced species often flourished.[63] Interestingly, more European species initially invaded the Americas than American species invaded Europe.[64] Despite the large number of weeds that were introduced, it is doubtful that land cover was significantly affected by them on either continent during the first 150 years. Subsequently, however, local ecosystems have been significantly modified by the introduction of weeds, though the degree of this change cannot be adequately quantified beyond the specific ecosystem.

Changes in the political economy of the Americas following the Columbian encounter also played an integrative role with technological and biotic changes to affect land use and land cover. Interestingly, these changes did not involve the introduction of commerce or, perhaps, profit. Amerindians had long engaged in major trade activities of both luxury and common goods that brought differential wealth to both individuals and communities. The scale of trade varied by locale, but, in the Mesoamerican and Andean realms, a large variety of markets reflected active, professional long-distance trade associations—some sponsored by the state—and the tributes or taxes flowed to the controlling powers. On his fourth voyage, Columbus himself caught a glimpse of Amerindian commerce when he intercepted a very large, fully loaded merchant canoe off the coast of present-day Honduras. The scale of commerce in certain regions was significant by any measure. The Aztecs, for example, accumulated enormous wealth through their state-sponsored merchants and their tribute demands. Extensive road networks were developed in some areas, particularly in the Andes, which assisted commerce and tribute payments.[65] Some areas even specialized in the production of long-distance trade products, such as salt on the Yucatán coast and cacao along the Pacific piedmont of Chiapas, Mexico, and in Guatemala.[66]

The political economy of the Spanish settlers, of course, changed the

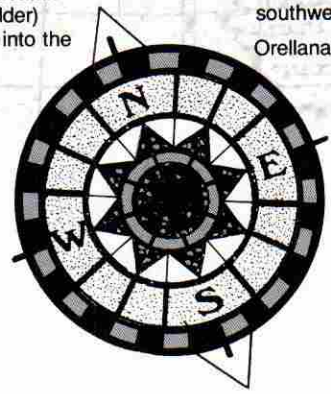
1539–42 Hernando de Soto explores the southeastern and south central regions of North America.

1531–63 Portugal systematically colonizes Brazil.

1527–47 Conquest of the lowland of the northern Yucatán Peninsula by Francesco de Montejo (the elder) begins, though Maya resistance continues into the 1800s.

1539–42 Francisco Vasquez de Coronado explores the North American southwest, including areas of Mexico.

Orellana explores the Amazon River.



beneficiaries of surplus and created two economies, one for the Spaniards and one for the remaining Amerindians. The creation of two economies was evidenced spatially through a dual settlement pattern. The important point for land use and land cover, however, was that commerce per capita increased as a result of long-distance ocean transport, the introduction of new technologies and biota, and Spanish control of the Amerindian labor force and former Amerindian lands and resources. These circumstances sustained the various Amerindian land uses, despite the overall collapse of the population. Amerindian depopulation, first in the Hispanic Americas and later in the Anglo-Americas, created conditions in which enormous expansion of new systems of land use was possible.

Among these new systems was the introduction of new plantation crops, particularly in the tropical lowlands. The plantation system, or the production of a single crop, particularly tree and shrub species, was not unknown to the Amerindians, who cultivated large cacao and other orchards in portions of the tropical lowlands. What was new, of course, was the Spanish control of production and labor on the plantation.[67] Most important among the new crops was sugar cane, plantations of which spread throughout the Caribbean islands and much of the humid portions of the gulf coast.[68] Small-scale plantations and livestock production replaced Amerindian agriculture in much of this area. The development of plantations in the Caribbean islands was achieved through the substitution of African slave labor for that lost through Amerindian depopulation. This change introduced the people of yet another continent into the post-Columbian encounter world. In this case, the people were experienced in tropical cultivation, and they developed a new system of land use that involved both open-field plow cultivation and intercropped orchard gardens.[69]

The Amerindians were not completely eradicated, however, particularly in the highlands, where the impact of European diseases may not have been as harsh as they were in the lowlands. Amerindian agriculture not only survived the initial encounter, but it also became a source of exchange between Amerindian and Spanish farmers. Each borrowed from and experimented with the other's practices and, over time, a new set of hybrid landscapes emerged that integrated many of the crops and cultivation techniques of both systems. In this process, however, many Amerindian cultigens were lost or forgotten, as was expertise in certain systems of production, such as the construction of wetland fields.[70]

Land-Use Changes in Europe

The Columbian encounter had direct consequences for land use in Europe, primarily through the "Columbian exchange," or the biotic transfers from one continent to the other.[71] The Spanish settlers were quick to send Amerindian crops back to Europe, and, after a period of experimentation, many of these imported plants became central to European agriculture. Potatoes, for instance, became a mainstay of northern Europeans, and corn became a major fodder crop. Tobacco and long-stemmed cotton also were readily adopted by Europeans. Other Amerindian plant imports include manioc, sweet potato, peanuts, beans, squash, tomatoes, chiles, pineapple, and cacao (a source of chocolate).

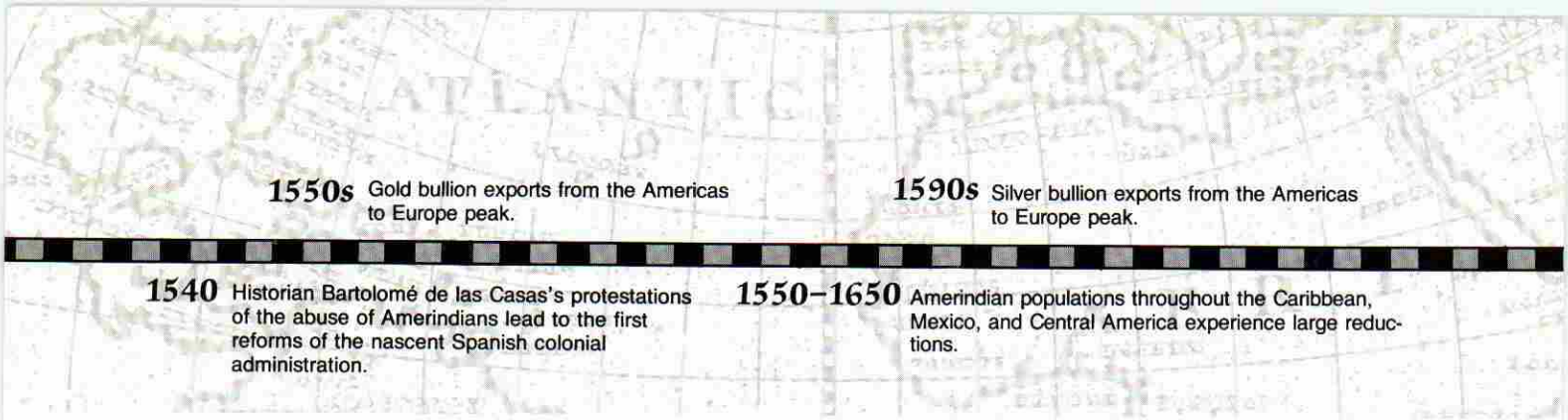
The direct impact of the imported crops on European land cover was that they replaced the previous cropland cover. The major indirect impact was that they helped to promote demographic and economic change worldwide. The potato, for example, improved the diet and health of poor northern Europeans because of its high caloric yield and thus contributed to the population growth of the continent.[72] Long-stemmed cotton, on the other hand, was essential for the industrialization of the textile industry. The subsequent population growth and industrialization of Europe, of course, had major consequences for land cover there and abroad, through the large-scale diffusion of European people, biota, and land uses and through the extraction of world resources to feed European industry.

From Encounter to Global Change

The Columbian encounter set into motion a series of continental land-cover changes, almost all of which were initially driven by the rapid ac-

ERRATUM

On page 18 of the July/August 1992 issue, the reaction of suspended solids in Lake Chad was said to reduce the water's acidity. In fact, the reaction increases the water's acidity.



cumulation of changes in land use. These changes, however, were not quite of the nature suggested by several currently popular "myths."[73] Specifically, at the time of the Columbian encounter, the European landscape had not been excessively degraded, and the agricultural systems used could have been continued—perhaps indefinitely. Also, Amerindian agricultural systems were not based solely or primarily on swidden agriculture, and the Americas at that time were not pristine wilderness. Moreover, after a period of adjustment, the new land uses introduced after the encounter were not unsustainable or exceptionally degrading to the environment.

Simply put, the land cover of both the Americas and Europe had been significantly modified by people prior to the Columbian encounter. These modifications varied in kind and scale according to local and regional levels of land use—coupled with the available biota and technologies—and the specific type of environment used. In both hemispheres, land-cover changes resulting from agricultural and environmental management had led to instances of agroenvironmental collapse as well as to sustainable systems of crop production.

Land-use and land-cover changes after the Columbian encounter, however, were the most immediate, direct, and profound in the Americas and were exacerbated by the catastrophic depopulation of the Amerindians and the biotic, technological, and economic changes instigated by the European settlers. The consequences of expansion of European land uses in environmentally unfamiliar regions led to some initial mistakes, but they were usually followed by sustainable management practices.

The following themes from studies of the Columbian encounter are particularly important for the assessment of contemporary global land-use and land-cover change:

Land Use and Degradation

- Significant land modification, even transformation, in the Americas is an ancient phenomenon and is not solely the product of post-Columbian encounter civilizations.
- The short-term land-use consequences of the Columbian encounter involved change far more than degradation.
- The land-use changes accumulated over time and resulted in significant, continent-wide alterations of land cover that ultimately would combine with similar changes elsewhere to contribute to contemporary global changes.
- The large-scale, sustained ecological degradation of the Americas is largely the product of the Industrial Age.

Deforestation

- Deforestation in the Americas was probably greater before the Columbian encounter than it was for several centuries thereafter.
- Many of the primeval forests that were supposedly encountered by the Europeans in 1492 and that remain today, including forests with the highest biodiversity, were not "pristine" or "virgin" but were the product of extensive use and modification by the Amerindians.
- The scale of deforestation, or forest modification, in the American tropics has only recently begun to rival that undertaken prior to the Columbian encounter.

Destruction of Grasslands and Grazing Lands

- The most radical land-use change in the Americas was the European introduction of large grazing animals, which dramatically increased native ungulate populations.
- Extensive areas of open or scrub forest and grasslands in the Americas were modified by Europeans and Amerindians for herding by reducing ground cover or by impeding forest regeneration through the burning of grasses.

Decline in Croplands

- Excluding grazing lands, cultivated lands decreased in the Americas subsequent to the Columbian encounter and probably did not return to their pre-encounter levels until the 18th or 19th centuries.

Understanding of these themes is essential for putting past and current land-use and land-cover changes in perspective and for connecting the Columbian encounter with contemporary global environmental change. Research leading to and following from UNCED is intricately involved in modeling environmental change to improve understanding of both the processes of change and the assessments of the environmental and societal consequences they imply. Also, patterns of land-use are essential for establishing the numerical range of the various modeling endeavors.

ACKNOWLEDGMENTS

The authors wish to thank W. M. Denevan and W. B. Meyer for their comments on this article and the Secretariat for the Scientific Committee on the Problems of the Environment (SCOPE) and SCOPE España for their interests in this subject. The authors also appreciate the assistance of Heather Henderson.

1600s Large-scale development of Old World livestock spreads throughout the Hispanic Americas, especially in Mexico and Argentina.

1604 France establishes the Quebec settlement in Canada.

1607 Great Britain establishes Jamestown, Virginia.

1620 Religious refugees from Great Britain settle Plymouth Colony in Massachusetts.

NOTES

1. A. W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe—900–1900* (Cambridge, England: University of Cambridge Press, 1986).

2. Some of the major considerations of the research community in preparation for UNCED can be found in "Recommendations from Sigma Xi and ASCEND 21," *Environment*, April 1992, 5.

3. An exception is the work of the International Geographical Union's Working Group on the Historical Geography of Global Environmental Change, led by V. Annenkov, of the Institute of Geography at the Russian Academy of Sciences. See also W. C. Clark and R. E. Munn, *Sustainable Development of the Biosphere* (Cambridge, England: Cambridge University Press, 1986).

4. For discussions of the relative roles of cumulative and systemic change, see Committee on Global Change, *Toward an Understanding of Global Change* (Washington, D.C.: National Academy Press, 1988); and B. L. Turner II et al., eds., *The Earth As Transformed by Human Action* (Cambridge, England: University of Cambridge Press, 1990).

5. B. L. Turner II et al., "Two Types of Global Environmental Change: Definitional and Spatial-Scale Issues in Their Human Dimensions," *Global Environmental Change: Human and Policy Dimensions* 1 (1990): 14–22.

6. R. W. Kates, B. L. Turner II, and W. C. Clark, "The Great Transformation," in Turner et al., eds., note 4 above; and W. L. Thomas, Jr., ed., *Man's Role in Changing the Face of the Earth* (Chicago, Ill.: University of Chicago Press, 1956).

7. J. F. Richards, "Land Transformation," in Turner et al., eds., note 4 above; M. Williams, "Forests," ibid.; and P. S. Martin and R. G. Klein, eds., *Quaternary Extinctions: A Prehistoric Revolution* (Tucson, Ariz.: University of Arizona Press, 1984).

8. Crosby, note 1 above; and A. L. Crosby, *The Columbian Exchange: Biological and Cultural Consequences of 1492* (Westport, Conn.: Greenwood, 1972).

9. K. Auchincloss, "When Worlds Collide," *Newsweek* (Columbus Special Issue), Fall/Winter 1991), 8. Despite the perception to the contrary, the academic community has been particularly diligent in exploring multiple themes about the Columbian encounter. Foremost among these is the traditional study of Native American Indian, or Amerindian, depopulation and cultural destruction. Specific to the quincentenary celebration, historians in Spain and the Americas have studied ethnic diversity, perceptions, and representations surrounding the Columbian encounter, while geographers have probed the meaning of exploration in the Americas using European and Amerindian maps, theories of the state of Amerindian landscapes in 1492, and the changes wrought by the European conquest. See K. W. Butzer, ed., *The Americas Before and After 1492*, vol. 82, no. 3 of *Annals of the Association of American Geographers* (1992).

10. The two myths can be found in a range of media, from scholarly to popular. See, for example, S. Shelter, "Three Faces of Eden," in H. J. Viola and C. Margolis, eds., *Seeds of Change: A Quincentennial Commemoration* (Washington, D.C.: Smithsonian Institution Press, 1991), 225–47; K. W. Butzer, "Geographers and the Columbian Encounter (Plenary address to the Association of American Geographers, Annual Meeting, San Diego, Calif., 20 April 1992); and Butzer, pages 345–68, note 9 above.

11. See, for example, K. Sale, *The Conquest of Paradise: Christopher Columbus and the Columbian Legacy* (New York: Knopf, 1990); and J. Weatherford, *Indian Givers: How the Indians of the Americas Transformed the World* (New York: Fawcett Columbine, 1988).

12. Sale, pages 175–76, note 11 above; and K. W. Butzer, "From Columbus to Acosta: Science, Geography, and the New World," *Annals of the Association of American Geographers* 82 (1992): 543–65.

13. See W. M. Denevan, "The Pristine Myth: The Landscape of the Americas in 1492," *Annals of the Association of American Geographers* 82 (1992): 369–85. See also M. J. Bowden, "The Invention of American Tradition," *Journal of Historical Geography* 18 (1992):3–26.

14. Examples include W. Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York: Hill and Wang, 1983); R. C. Harris, ed., *Historical Atlas of Canada: From the Beginnings to 1800* (Toronto: University of Toronto Press, 1983); D. W. Meinig, *The Shaping of America: Atlantic America, 1492–1800* (New Haven, Conn.: Yale University Press, 1986); R. D. Mitchell and P. A. Groves, eds., *North America: Historical Geography and a Changing Continent* (Totowa, N.J.: Rowman and Littlefield, 1987); J. J. Parsons, *Hispanic Lands and Peoples: Selected Writings of James J. Parsons*, W. M. Denevan, ed. (Boulder, Colo.: Westview Press, 1983); C. O. Sauer, *The Early Spanish Main* (Berkeley, Calif.: University of California Press, 1966): C. O. Sauer, *Sixteenth-Century America: The Land and People as Seen by the Europeans* (Berkeley, Calif.: University of California Press, 1971); and R. C. West, "Aboriginal and Colonial Geography of Latin America," in B. W. Blouet and O. M. Blouet, eds., *Latin America* (New York: Wiley, 1982), 34–86.

15. This article specifically draws on such recent efforts as the Scientific Committee on Problems of the Environment, "Principles, Patterns and Processes: Some Legacies of the Columbian Encounter," Eighth General Assembly, Sevilla, Spain, 21–22 January 1992, and the special quincentenary edition of the *Annals of the Association of American Geographers*, note 9 above.

16. K. W. Butzer, "The Realm of Cultural-Human Ecology: Adaptation and Change in Historical Perspective," in Turner et al., eds., note 4 above.

17. C. Pfister, *Bevölkerung, Klima, und Agarmodernisierung 1525–1860* (Berne, Switzerland: Haupt, 1984). For a general discussion of population cycles, see D. B. Grigg, *Population Growth and Agrarian Change: An Historical Perspective* (Cambridge, England: Cambridge University Press, 1980).

18. M.'Williams, "Forests," in Turner et al., eds., note 4 above; and H. C. Darby, *The Changing Fenland* (Cambridge, England: Cambridge University Press, 1983).

19. See Y.-F. Tuan, "Discrepancies Between Environmental Attitude and Behavior: Examples from Europe and China," *Canadian Geographer* 12 (1968): 176–91. See also T. Whitmore et al., "Long-Term Population Change," in Turner et al., eds., note 4 above.

20. F. González-Bernáldez, "Western Mediterranean Land Use as Antecedents for Semiarid America" (Paper presented at the Scientific Committee on Problems of the Environment, Eighth General Assembly, Sevilla, Spain, 21–22 January 1992); K. W. Butzer, "Cattle and Sheep from Old to New Spain: Historical Antecedents," *Annals of the Association of American Geographers* 78 (1988): 29–56. Also, see the papers delivered at the symposium "Arqueologia: La Huella del Hombre en el Ecosistema Mediterráneo," Universidad Internacional Melendez-Pelayo, Valencia, Spain, 1–5 July 1991.

21. J. F. A. Merino and A. Martin, "Landscape Changes in the Last 500 Years in the Guadalaquivir River Valley: With Special Reference to Doñana National Park" (Paper prepared for the Scientific Committee on Problems of the Environment, Eighth General Assembly, Sevilla, Spain, 21–22 January 1992); Butzer, note 16 above; K. W. Butzer, "Climatic Variation as a Co-Variable in Historical Process: The Role of Food Stress and Famine" (Paper presented at the symposium "What is the Engine of History," Texas A & M University, College Station, Texas, 26–29 October, 1988).

22. W. M. Denevan, *The Population of the Americas in 1492*, 2d ed. (Madison, Wis.: University of Wisconsin Press, 1992).

23. Ibid.

24. For an assessment of Mesoamerica at the time of the Columbian encounter, see T. M. Whitmore and B. L. Turner II, "The Cultivated Landscapes of Mesoamerica," *Annals of the Association of American Geographers* 82 (1992): 402–25.

25. R. A. Donkin, *Agricultural Terracing in the Aboriginal New World*, Viking Fund publications in anthropology, no. 56 (Tucson, Ariz.: University of Arizona Press, 1979).

26. W. E. Doolittle, *Pre-Hispanic Occupance in the Valley of Sonora, Mexico: Archaeological Confirmation of Early Spanish Reports*, anthropological papers of the University of Arizona, no. 48 (Tucson, Ariz.: University of Arizona Press, 1988).

27. No one has undertaken the formidable task of estimating the total area of Amerindian terracing in the pre-Columbian Americas. This area certainly equaled millions of hectares, however. Peru alone is estimated to have had 600,000 hectares, not counting the eastern Andean slopes, where forests cover abandoned terraces and inhibit calculations. W. M. Denevan, "Measurement of Abandoned Terracing from Air Photos: Colca Valley, Peru," *Yearbook: Conference of Latin Americanist Geographers* 14 (1988): 20–30.

28. In the basin of Mexico (the area surrounding present-day Mexico City), open fields were known as *acamellonada*, or filled with planting mounds. T. Rojas Rabeila, *Las Simebras de Ayer: La Agricultura Indigena del Siglo XVI* (Mexico, D. F.: Secretaría de Educacion Pública, 1988). The precise form of field raising used and the functions performed varied according to the environment and the crops used. H. D. Thurston, *Sustainable Practices for Plant Diseases in Traditional Farming Systems* (Boulder, Colo.: Westview Press, 1991); and G. C. Wilken, *Good Farmers: Traditional Agricultural Resource Management in Mexico*

1625–35 England and France inaugurate large-scale sugar plantations in the West Indies.

1680 Introduction of the horse to North American Indians gives rise to the mounted warriors of the North American plains encountered by Europeans.

1670 Great Britain establishes the Hudson Bay Company in North America to begin the systematic exploitation of fur-bearing animals.

and Central America (Berkeley, Calif.: University of California Press, 1987).

29. W. E. Doolittle, "Food Production Systems of North America on the Eve of Contact," *Annals of the Association of American Geographers* 82 (1992): 386–401.

30. Ibid.; W. E. Doolittle, *Canal Irrigation in Prehistoric Mexico: The Sequence of Technological Change* (Austin, Tex.: University of Texas Press, 1990); G. W. Knapp, "Reigo Precolonial en la Sierra Norte," *Ecuador Debate* 14 (1987):17–45; and D. Guillet, "Terracing and Irrigation in the Peruvian Highlands," *Current Anthropology* 28 (1989): 409–18.

31. Doolittle, note 29 above.

32. J. F. Bergmann, "The Distribution of Cacao Cultivation in Pre-Columbia America," *Annals of the Association of American Geographers* 59 (1969): 85–96.

33. Whitmore and Turner, note 24 above; and W. M. Denevan, "Aboriginal Drained-Field Cultivation in the Americas," *Science* 169 (1970): 647–54.

34. A. H. Siemens et al., "Evidence for a Cultivar and a Chronology from Patterned Wetlands in Central Veracruz, Mexico," *Science* 22 (1988): 105–7; and B. L. Turner II and P. D. Harrison, ed., *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize* (Austin, Tex.: University of Texas Press, 1983).

35. The literature on *chinampa* agriculture is large. See, for example, J. H. Parsons, M. H. Parsons, V. Popper, and M. Taft, "Chinampa Agriculture and Aztec Urbanization in the Valley of Mexico," in I. S. Farrington, ed., *Prehistoric Intensive Agriculture in the Tropics* (Oxford, England: British Archaeological Reports, 1985, 49–96; and C. Niederberger, *Paléopaysages et Archéologie Pré-Urbaine du Bassin de Mexico (Méxique)*, vol. 1 (Mexico City, Mexico: Centre d' Estudes Méxicaines et Centraméricaines, 1987), 75–116.

36. C. Plazas and A. M. Falchetti, "Poblamiento y Adecucación Hidráulico en el Bajo Rio San Jorge, Costa Atlantica, Colombia," in W. M. Denevan, K. Mathewson, and G. Knapp, eds., *Prehistoric Agricultural Fields in the Andean Region* (Oxford, England: British Archaeological Reports, 1988), 483–503.

37. R. C. Anderson, "The Historic Role of Fire in the North American Grassland," in S. L. Collins and L. L. Wallace, eds., *Fire in North American Tallgrass Prairies*, (Norman, Okla.: University of Oklahoma Press, 1990), 8–18; and C. O. Sauer, "Grassland Climax, Fire, and Man," *Journal of Range Management* 3 (1950):16–21.

38. Denevan, note 13 above; and W. M. Denevan, *The Upland Pine Forests of Nicaragua* (Berkeley, Calif.: University of California Publications in Geography, 1961), 251–320.

39. Denevan, note 13 above; D. Foster, "Forest Change and Resilience: The Post-Columbian Dynamics of the Forest Landscape of New England" (Paper presented at the Scientific Committee on Problems of the Environment, Eighth General Assembly, Sevilla, Spain, 21–22 January 1992); and Williams, note 18 above.

40. N. Smith, "Human-Induced Landscape Changes in Amazonia and Implications for Development" (Paper presented at the Scientific Committee on Problems of the Environment, Eighth General Assembly, Sevilla, Spain, 21–22 January 1992); and A. H. Siemens, "Land Use Succession in the Gulf Lowlands of Mexico: A Long View," ibid.

41. See W. M. Denevan, "Stone vs. Metal Axes: The Ambiguity of Shifting Cultivation In Prehistoric Amazonia," *Journal of the Steward Anthropological Society* 20 (1991–1992); and Doolittle, note 29 above.

42. Whitmore and Turner, note 24 above; and A. Gómez-Pompa, J. S. Flores, and V. Sosa, "The 'Pet Kot': A Man-Made Tropical Forest of the Maya," *Interciencia* 12 (1987):10–15.

43. Foster, note 39 above; M. L. Heinselmand, "Fire and Succession in the Conifer Forest of Northern North America," in D. C. West, H. H. Shugart, and D. B. Botkin, eds., *Forest Succession* (New York: Springer, 1981), 374–405; and P. K. Schoonmaker and D. Foster, "Some Implications of Paleoecology for Contemporary Ecology," *The Botanic Review* 57 (1991):204–45.

44. See J. S. Farrington and C. C. Park, "Hydraulic Engineering and Irrigation Agriculture in the Moche Valley, Peru: c. A.D. 1250–1532," *Journal of Archaeological Science* 5 (1978):255–68; K. W. Butzer, "Ethno-Agriculture and Cultural Ecology in Mexico: Historical Vistas and Modern Implications," *Geographers' Research on Latin America: Benchmark 1990, Yearbook, Conference of Latin American Geographers* 17–18 (forthcoming); R. Hassig, "The Famine of One Rabbit: Ecological Causes and Social Consequences of a Pre-Columbian Calamity," *Journal of Anthropological Research* 37 (1981):171–82; and B. J. Williams, "Contact Period Rural Overpopulation in the Basin of Mexico: Carrying Capacity Models Tested with Documentary Evidence," *American Antiquity* 54 (1982):715–32.

45. F. Tudela, "Deep Land Use Changes in Colonial America: A Systemic Approach" (Paper presented at the Scientific Committee on Problems of the Environment, Sevilla, Spain, 21–22 January 1992); and I. Douglas and R. I. Hodgson, "Western Europe and the Western Hemisphere, 18th–20th Centuries: Magnitudes and Impacts of Land Cover Changes," ibid.

46. F. Braudel, *Civilization and Capitalism 15th–18th Century*, vol. 1 (New York: Harper and Row, 1982); and W. Barrett, "World Bullion Flows: 1450–1800," in J. D. Tracy, ed., *The Rise of Merchant Empires* (Cambridge, England: Cambridge University Press, 1990), 224–54.

47. Braudel, note 46 above.

48. Denevan, note 22 above.

49. See T. M. Whitmore, *Disease and Death in Early Colonial Mexico: Simulating Amerindian Depopulation* (Boulder, Colo.: Westview Press, 1992).

50. See Denevan, note 41 above; and N. D. Cook and W. G. Lovell, eds., *Secret Judgement of God: Old World Diseases in Colonial Spanish America* (Norman, Okla.: University of Oklahoma Press, 1991).

51. See Butzer, note 9 above.

52. See Cronon, note 14 above; and Foster, note 39 above.

53. K. W. Butzer, "Spanish Conquest Society in the New World: Ecological Readaptation and Cultural Transformation," in S. T. Wong, ed., *Geoscience and Man* 31 (forthcoming).

54. González-Bernáldez, note 20 above.

55. Butzer, note 53 above.

56. Whitmore and Turner, note 24 above.

57. R. M. Denhardt, *The Horse of the Americas* (Norman, Okla.: University of Oklahoma Press, 1975).

58. Butzer, note 53 above.

59. D. Watts, *The West Indies: Patterns of Development, Culture, and Environmental Change Since 1492* (Cambridge, England: Cambridge University Press, 1987).

60. Siemens, note 40 above. In regard to vegetation change in early colonial Mexico, see K. W. Butzer and E. K. Butzer, "Transfer of the Mediterranean Livestock Economy to New Spain: Adaptation and Consequences" (Paper presented at the Scientific Committee on Problems of the Environment, Eighth General Assembly, Sevilla, Spain, 21–22 January 1992).

61. F. Chevalier, *Land and Society in Colonial America* (Berkeley, Calif.: University of California Press, 1963).

62. Butzer and Butzer, note 60 above.

63. Crosby, note 1 above. See also, H. A. Mooney and J. A. Drake, "The Ecology of Biological Invasions," *Environment*, June 1987, 10.

64. R. H. Groves, "Exchanges of Weeds Between the Americas and Mediterranean Europe" (Paper presented at the Scientific Committee on Problems of the Environment, Eighth General Assembly, Sevilla, Spain, 21–22 January 1992).

65. Sauer, pages 128–29, note 14 above; Hassig, note 44 above; and C. D. Trombold, ed., *Ancient Road Networks and Settlement Hierarchies in the New World* (Cambridge, England: Cambridge University Press, 1991).

66. A. P. Andrews, *Maya Salt Production and Trade* (Tucson, Ariz.: University of Arizona Press, 1983); and Bergmann, note 32 above.

67. See Whitmore and Turner, note 24 above.

68. J. L. Del Rio, *Los Inicios de la Agricultural Europea en el Nuevo Mundo* (Seville, Spain: ASAJA, 1991).

69. C. T. Kimber, *Martinique Revisited: The Changing Plant Geographies of a West Indian Island* (College Station, Tex.: Texas A&M Press, 1988); and R. L. Hall, "Savouring Africa in the New World," in H. J. Viola and C. Margolis, eds., *Seeds of Change* (Washington, D.C.: Smithsonian Institution Press, 1991): 161–69.

70. D. W. Gade, "Landscape, System, and Identity in the Post-Conquest Andes," *Annals of the Association of American Geographers* 82 (1992):461–77; and Whitmore and Turner, note 24 above.

71. Crosby, note 8 above; and Douglas and Hodgson, note 45 above.

72. E. J. Hamilton, "What the New World Gave the Economy of the Old" in F. Chiappelli, M. J. B. Allen, and R. L. Benson, eds., *First Images of the Americas*, vol. 2 (Berkeley, Calif.: University of California Press, 1976), 853–84; P. Londe, "New World Foods, Old World Diet," *Aramco World* 43 (1992):47–55; and W. L. Langer, "American Foods and Europe's Population Growth, 1750–1850," *Journal of Social History* 8 (1975):51–66.

73. Denevan, note 13 above; and Butzer, note 10 above.