# 1 Biological Transfer, Agricultural Change, and Environmental Implications of 1492

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## ABSTRACT

The Columbian Exchange involved not only a transfer of germplasm between two hemispheres on an unprecedented scale, but also the readaptation of agrosystems, representing distinctive crop repertoires, risk strategies, management techniques, cuisines, and values. The European colonists brought an agrosystem to the New World that was primarily derived from the Mediterranean Basin; its success varied greatly, depending on environmental compatibility and economic or cultural competition with indigenous alternatives. Similarly, existing New World agrosystems responded to the new agronomic information by incorporating many Old World crops, sometimes with their attached management practices; both the Mexican and Andean agrosystems were hybridized, but they have successfully retained their identities up to the present. This chapter seeks to understand the actual processes of systemic change and interaction, within the Spanish colonial sphere, from ecological and historical perspectives. Indigenous adaptation of Old World germplasm apparently was overwhelmingly voluntary, in response to new agricultural, nutritional, and economic opportunities, much as the global migration of food crops has been benign, improving the quality of human life worldwide. The chapter also examines the impact of European agrotechnology on New World environments, and does not find support for the currently popular hypothesis of colonial devastation.

The 500th anniversary of 1492 brought more than enough media coverage, commercial exploitation, and ideological polarization. But that should neither deter nor distract the scientific community from reexamining the aftermath of 1492 in a longer, historical perspective. The Columbian Quincentenary marks an encounter that opened the two hemispheres to human and biotic exchange. The direct impacts, the complex feedbacks, and the continuing implications of that intercontinental exchange are pertinent subject matter for most of the natural and social sciences (Butzer, 1992a).

Cultural ecologists are interested in how people manage resources by a range of strategies regarding diet, technology, settlement, reproduction, and the necessary systemic maintenance between them. The environment, as the wherewithal of long-term survival, is integral to such research. Agriculture is equally fundamental in cultural behavior and the alternative strategies that different societies choose. A great deal of common ground exists between cultural ecology and macro-agronomy, and this chapter will explore a number of themes that concern both fields, despite their distinct perspectives and methods.

## MEDITERRANEAN AGROSYSTEM AS DATUM FOR EUROPEAN COLONIZATION

It can be argued that Europeans brought several variants of what basically is a Mediterranean agroecosystem to the Americas. That agrosystem had coalesced over thousands of years (Zohary & Hopf, 1993), and was predicated on four complementary strategies that reduced subsistence risk: (i) outfield cultivation of certain grains and legumes; (ii) infield or horticultural tending of a package of garden vegetables, condiments, and herbals; (iii) orchard propagation of tree crops that provided oil, wine, and fresh or dried fruits; and (iv) a choice of several options to integrate animal husbandry into agricultural operations, as sources of manure and alternative proteins and fats (Vassberg, 1984; Butzer, 1993, 1994). As a combination, that agrosystem is archaeologically and linguistically verified in the Aegean world by about 1500 B.C. It had dispersed and been adapted to the full range of lowland Mediterranean environments about 2500 years ago, cross-cutting several different cultural traditions between the Near East and the Iberian Peninsula (Butzer, 1988a; Fig. 1–1).

At one level, this Mediterranean agrosystem was distinguished from earlier, more generalized types of farming by the integration of horticulture and arboriculture in the form of well-defined pursuits, probably as a substitute for the harvesting of wild plant foods. At another level, it was characterized by a particular cuisine, marked by great diversity, and focused on three components with age-old symbolic value: wheat (see Appendix) bread, wine, and olive oil. In effect, it was both a strategic and a cultural choice, balancing solutions to risk with equally deep-seated cultural values (on the cultural role of cuisine, see Harris & Ross, 1987). Within these general norms, considerable variability is evident, reflecting millennia of experience and innovation, environmental detail, and local ethnohistorical trajectories (Butzer, 1994). As in most tested agrosystems, considerable flexibility characterized specific crops or technology, the management of soil productivity, and the response to commercial incentives. In addition to incremental intensification of the system as a result of ongoing innovations, long-term, cyclical trends toward greater or lesser intensification reflected demographic change and urban market demand (Butzer, 1990).

In Roman times, this specific agrosystem was then expanded to European environments where olive oil could not be produced and where vine cultivation was marginal; the system moved specifically into the cooler upland regions of the Mediterranean Basin and the higher latitudes of western Europe (Fig. 1–1). This can now be clearly documented by archaeobotanical evidence, which showed that Roman military encampments and elite farms both imported and produced a new range of horticultural plants, tree fruits, and even new grains (Zeist et al., 1991). Documentary evidence from the ninth century showed that these new food preferences not only survived the Dark Age, but had become truly indigenous traits. This inevitably required considerable compromise. Wine competed with beer as an alcoholic beverage, bread wheat was mixed with rye or substituted by hulled spelt in the baker's loaf, and animal fats were the custom, with olive oil preserved only in the sacramentals of the Christian Church. But both the peasant's and the monk's meal around A.D. 800 included cabbage, leek, cucumber, and radish, as well as a wide array of condiments once limited to Mediterranean hill-sides (Butzer, 1993). The last also provided new herbal remedies, while dried apple, pear, and peach hung under the roof in the wintertime.

During the course of the Middle Ages, this modified form of the Mediterranean agrosystem expanded spontaneously, throughout eastern Central Europe and even into northwestern Europe, where older forms of dairy farming remained prominent, as they did in the Alps. This heavy livestock component helped mitigate the problem of mediocre yields, which were improved by switching to mouldboard plows and triple crop rotation. Yet despite the various modifications and modest innovations, agriculture in temperate Europe was still practiced according to a seasonal calendar that would have been familiar to Columella or Palladius in its broad lines: winter wheat, summer barley and legumes, hay-making on fallow fields or wet meadows, winter stabling of livestock to storepile manure for outfield and garden cultivation, sequential tending of orchards or vineyards, and the grazing of animals on whatever land was left over (Butzer, 1993).

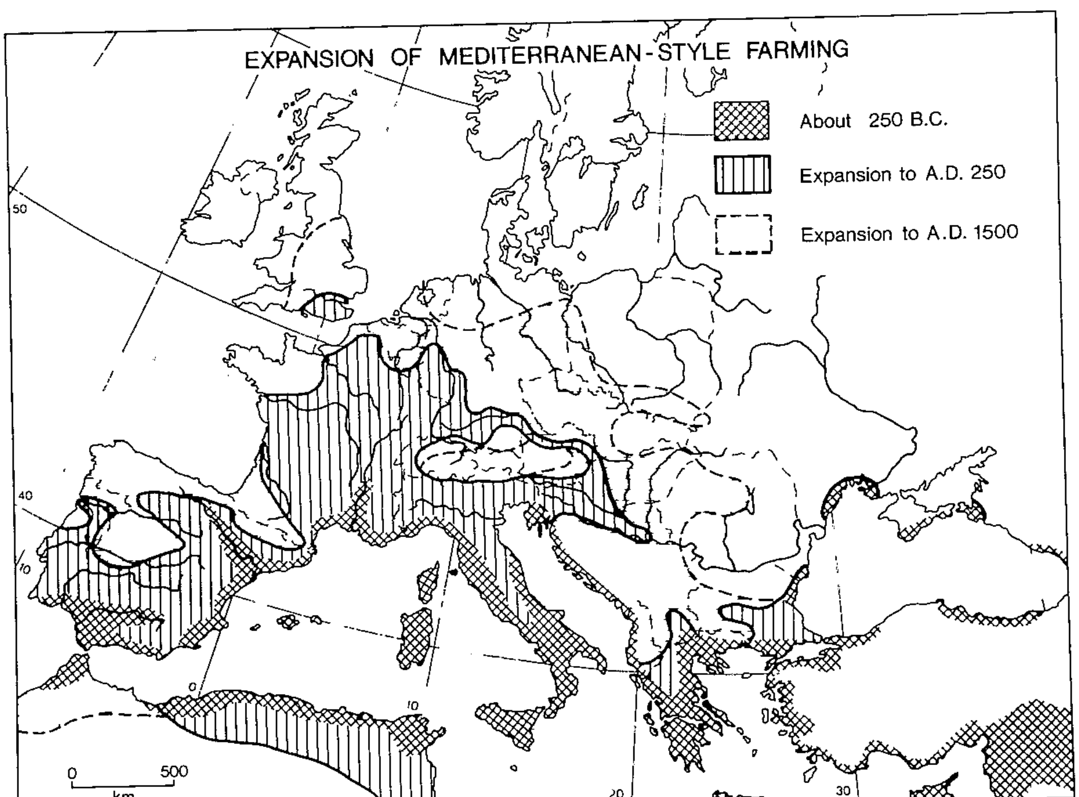


Fig. 1–1. The original Mediterranean Agrosystem and its Expansion until about 1500.

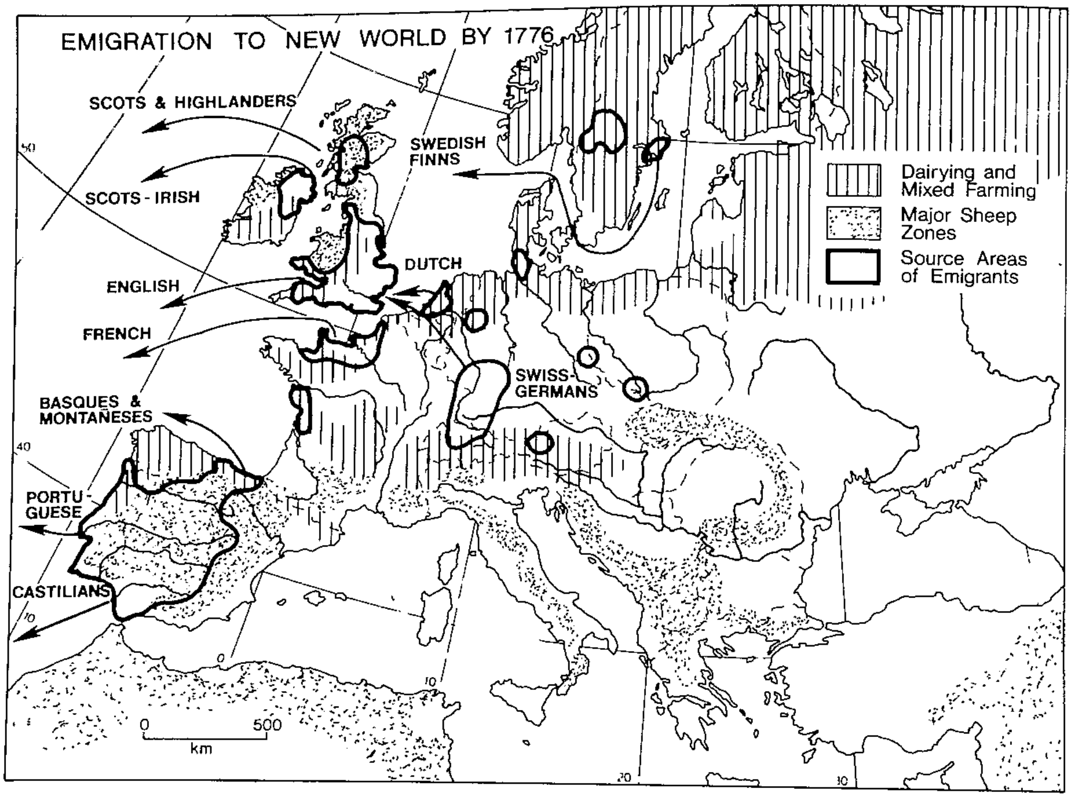


Fig. 1–2. Emigration to the New World by 1776. Source Areas of Settlers based, in part, on Boyd-Bowman (1976), Harris and Warkentin (1974), and Jordan and Kaups (1989)

Fortuitously, almost all the regions that supplied the colonists for the New World had been firmly drawn into either a typical or modified form of this Mediterranean agrosystem before 1492. Subsistence strategies and culinary tastes were broadly similar. Even in the cultural and ideological realm, despite growing dissonance after the Reformation, the commonalities of attitude and lifestyle transcended the differences of language and political units.

As a result, European settlers from Britain, France, Holland, Germany, Spain, and Portugal brought essentially one and the same agrosystem to the Americas (Fig. 1–2). The work calendar, dietary preferences, and the implanted values differed only in their details. But in the New World, these settlers encountered unfamiliar ecological diversity as well as environments that were unsuitable for their kind of farming, or that required considerable readaptation for eventual success. They also encountered indigenous peoples with different crops and technologies, embedded in unfamiliar lifeways, cultural attitudes, and food-preferences (Armelagos, 1992). Europeans not only sought to conquer the indigenous peoples, but also to impose their own agrosystem. Across vast areas it modified or replaced indigenous strategies, cuisines, and their associated values. As a result, the staple foods and related management strategies of Europe became dominant in most of North America and in parts of South America (Fig. 1–3) to begin a process of global homogenization.

This chapter will examine the processes of selection in the Mediterranean agrosystem, which was adapted or substituted in the New World. The issues will

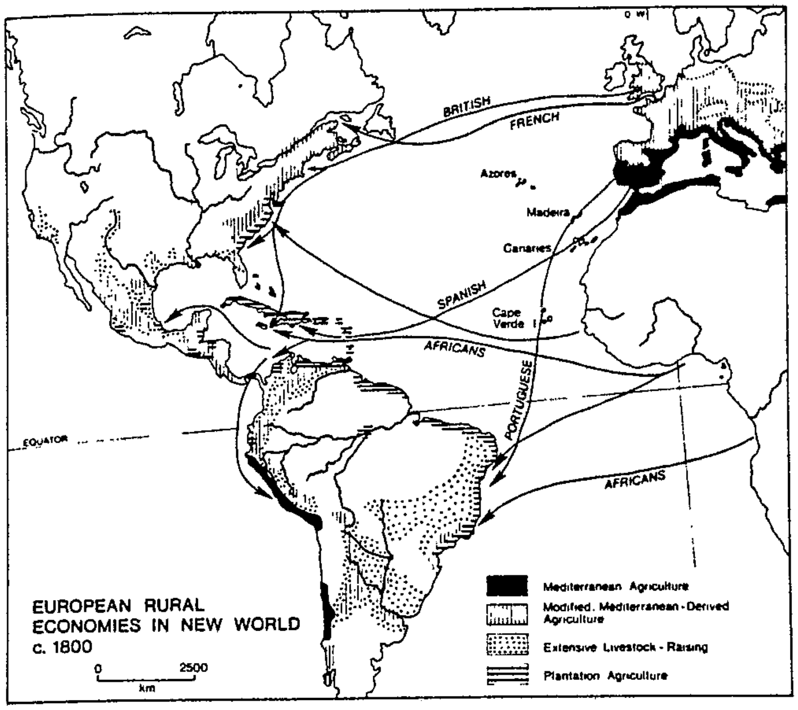


Fig. 1–3. European Rural Economies in the New World about 1800.

be examined empirically, using contemporary sources to elucidate how such processes affected individual cultivars and the agrostrategies of which they formed a part. The interactions between the Old and New World agrosystems are discussed, focusing on the Spanish colonial domain before 1650. Finally, the ecological impact of the Mediterranean agrosystem on the New World will be addressed in order to dispel some persistent misconceptions.

## SELECTION AND ADAPTATION OF THE MEDITERRANEAN CULTIVARS IN THE NEW WORLD

The comparative success or failure of the Mediterranean agrosystem in the New World was predicated on (i) readaptation to different and highly variable environments, (ii) economic competition with indigenous plants for permanent econiches, and (iii) the accidents of planned or spontaneous introduction. These processes have been minimally studied, although they are reasonably accessible by virtue of good, but underexploited Spanish sources of the 16th and early 17th centuries. The best of these early sources can be briefly reviewed:

1. Gonzalo Fernández de Oviedo (1959) wrote the first natural history of the New World, providing systematic information on indigenous economic plants as well as a report on the status of Spanish cultivars on Hispaniola as of 1535. He is complemented by the Franciscan friar Toribio de Motolinía (1971), who made cogent observations on the difficulties of adapting Spanish fruit trees in Mexico around 1540.

2. During the 1570s, the Spanish administrative office responsible for the Indies sent out systematic questionnaires to all local magistrates in the colonies. The results, known as the *relaciones geográficas*, date between 1571 and 1586 and provide an extensive, but incomplete record for most of the Spanish American provinces; almost all have now been published in Spanish. Coverage is particularly good for Mexico and Guatemala (Acuña, 1984–1988), and for Ecuador (Jiménez de la Espada, 1965); selected areas of the West Indies, Venezuela, Peru, and Argentina also are represented (Latorre, 1919; Jiménez de la Espada, 1965). In Mexico and Guatemala, some 75% of these reports come from indigenous settlements, and are largely based on native informants. Elsewhere almost all were gathered for Spanish settlements and reported by colonial officials or clerics. But the questionnaires specifically inquired about indigenous *and* Spanish economic plants, so that all give explicit, local information on both categories of crops, and the degree to which they were successful at the time. Providing such data for >200 towns and their dependent villages, the *relaciones* form an invaluable resource[1].

3. In 1574, the Spanish government geographer, Juan López de Velasco (1971), prepared a comprehensive overview of the various colonies, their environments, towns, settlers, indigenous peoples, and agricultural economy. This was based on early responses to the questionnaire as well as a host of reports of the previous 20 years, many of them now lost or inaccessible. Velasco was particularly interested in the status of Spanish agriculture and discussed why certain crops had failed in some areas.

4. In 1630, the Carmelite, Antonio Vázquez de Espinosa (1969), completed a manuscript based on 14 years of travel and service in most of the Spanish domains. His remarks on local agricultural products were based on church or government documents, as well as personal observations. They provide welcome data on areas such as Venezuela, Colombia, Peru, and Chile.

5. Finally, in 1652, the Jesuit scholar Bernabé Cobo (1956) concluded a major work, with a substantial segment on Spanish cultivars, based on 40 years of experience in Peru and 12 years in Mexico. He discussed the success of each plant in Peru, with respect to ecology and competitive indigenous crops, adding valuable historical details on their introduction or their changing market prices and availability. Cobo (1956) provides an essential qualitative overview of the whole process. This evidence is complemented by a good synthesis of various minor works for the West Indies and tropical South America by V.M. Patiño (1969).

The most fundamental problem encountered by the Spanish settlers in the Americas was an ecologically-complex, tropical world that was hardly ideal for their Mediterranean agrosystem. From southern Mexico to Bolivia, seasonal contrasts of temperature were small, while towards the equator, diurnal amplitudes

[1] Some 120 of these are concentrated in central and western Mexico, representing the majority, but by no means all Indian or Spanish settlements. But the number is large enough to serve as a representative sample, quantifiable by the number of locations in which a particular cultivar was used. Our evaluation for Mexico is consequently based on a system of scoring, with some 1850 entries, to rank the most important food crops. An earlier effort in this direction was made by Moreno (1968), who compiled and mapped a selection of key cultivars.

were greater than seasonal differences. The lowlands were frost-free and, in part, very wet, while at higher elevations and lower latitudes, nightly frosts could be experienced through much of the year. The rainy season also coincided with the warmest months. All this required adjustments or even radical changes in the familiar repertoire of adapted cultivars. After an initial period of trial and error and unwitting genetic selection, some plants were found to thrive, while others did not, and were gradually abandoned, unless they proved successful somewhere else.

In effect, the agrosystem had to be disassembled, each element tested more or less independently, after which the viable components could be reassembled; sometimes the outcome was a modified and simplified version of the Mediterranean agrosystem; at other times, the basic rationale of that system had to be abandoned, and substitute staples found, while retaining whatever familiar signposts that had passed the test. These early years of agroecological trial and error must have been very difficult, and whatever the eventual outcome, they required a reassessment of resource priorities, technological adjustments, shifts in seasonal strategies, and new attitudes to risk management.

## The Humid, Tropical Lowlands

In 1493, Columbus arranged to bring a standard selection of Mediterranean seed stocks to Hispaniola, which failed. The agronomic results of the second settlement of that island in 1503 were little different, except that substitute staples began to be tested. When Cortés assembled his flotilla on Cuba, to explore the Mexican coast in 1519, it was provisioned with salted pork and cassava cakes. It soon became evident that Mediterranean grains could not be grown in the humid tropical lowlands, while most of the familiar fruit trees barely blossomed, and at least 11 kinds of house or garden plants would not produce seed. Lacking a cold climate signal (vernalization), wheat sprouted at any time of the year, frustrating efforts at harvest, while the ears repeatedly succumbed to blight during the rainy season. Those fruit trees that required weeks of cool weather before developing blossoms produced poorly, and their paltry products were small and were distasteful. Other fruit trees were relentlessly attacked by ants (*Formica sanguinea*). But citrus trees, derived from the Moorish dominion and limited to the warmer coastlands of Spain, did exceptionally well, even expanding into the surrounding forests, where they could be picked like a wild resource. Dates, barely viable in Spain, were introduced because of the impression that palms thrived on Hispaniola; they produced stately ornamentals, but dates were few and of poor quality.

As a result, only the impoverished structure of the Mediterranean agrosystem survived in the humid tropics—as a limited selection of horticultural crops and orchard trees, together with Indian staples and Moorish fruit trees (Table 1–1). The exploding populations of cattle (see Appendix) and pigs provided an unfamiliar plenitude of cheap meat, but since Spaniards claimed that cassava did not agree with their digestion, the wealthy were willing to pay high prices for imported wheat. Even their efforts to emulate the Portuguese example of sugar plantations on the Atlantic islands ultimately failed, because of the difficulty of ob-

Table 1–1. Spanish Agro-Strategies in different New World Environments before 1650 (only representative crops are listed, in order of importance).

Highland Mexico (Low latitudes, temperate, montane; irrigated)
- Field Crops: Wheat, barley (fodder), with increasing commercial maize†
- House Gardens: Fava bean, cabbage, chickpea, lettuce, radish, onion, garlic, mint, coriander
- Orchards: Peach, quince, apple, pear, fig, grape but no wine
- Livestock: Primary in peripheral areas, dominated by cattle, sheep, horses

Gulf-Caribbean and Pacific Coastlands (Humid, tropical lowlands; locally irrigated)
- Field Crops: Maize,† cassava,† later also rice
- House Gardens: Melon, cucumber, turnip, cabbage, carrot
- Orchards: Citrus, fig, grape
- Livestock: Cattle, horses/mules, pigs
- Plantations: Cacao,† sugar, cotton,† indigo,† tobacco,† ginger
- Extractive: Timber† and dyewoods†

Andean and Central American Highlands (Low latitudes, warm-temperate, montane; mainly irrigated)
- Field Crops: Wheat, with some maize† and barley (fodders)
- House Gardens: Cucumber, melon, chickpea, cabbage, lettuce, onion, eggplant, garlic, alfalfa, rose, and Mediterranean condiments (coriander, parsley, fennel, pennyroyal)
- Orchards: Peach, pomegranate, grape, fig, and citrus; local wine production
- Livestock: Primary in rural areas: cattle, merino sheep, pigs, horses/mules
- Plantations: Local henequen† and sugar

Coastal Peru and Chile (Arid to subhumid, coastal lowlands; irrigated)
- Field Crops: Wheat; also maize,† barley, and alfalfa as fodder
- House Gardens: Cucumber, melon, eggplant, lettuce, radish, and rose
- Orchards: Quince, pomegranate, fig, with substantial wine and olive oil production
- Livestock: Subordinate, mainly goats, pigs, horses
- Plantations: Local sugar
- Extractive: Timber†

Argentina and Paraguay (Subtropical, subhumid lowlands; mainly irrigated)
- Field Crops: Wheat, some maize†
- House Gardens: Chickpea, fava bean, rose
- Orchards: Grape, peach, fig, quince, pomegranate, citrus; local wineproduction
- Livestock: Primary rural enterprise, especially cattle and horses/mules
- Plantations: Some sugar and cotton†

† Indicates New World origin.

taining slave labor, as the indigenous peoples died due to Old World epidemics. Small wonder that the Caribbean colonies were shunned by further settlers, and even departure prohibitions were unsuccessful in keeping old residents in place, in so far that they did not succumb to tropical diseases. By 1600, the Spanish presence in the Gulf-Caribbean lowlands was largely limited to strategic port cities and an isolated, colonial microcosm on the subhumid Yucatan Peninsula.

## The Mexican Highlands

When Cortés surveyed the cool Mexican plateau in 1519, he recognized its similarity to the interior Spanish plateaus (the Meseta), and promptly requested seed stocks and livestock from Madrid. Within 5 years, he was actively promoting wheat cultivation and personally investing in well-selected agricultural enterprises (Prem, 1992). But succeeding governments were reluctant to dispossess Indian agricultural land, and indigenous farmers were equally reluctant to plant wheat, which only thrived during the dry season with irrigation. Dry-farming during the rainy winters, the dominant pattern in Spain, was precarious in the New World by virtue of unpredictable fall or spring rains, and also was endangered by recurrent late season frosts. Blight precluded planting for the wet, summer months. Only during the 1560s and 1570s did large-scale wheat cultivation, in warmer, irrigated valleys, begin to meet market demand. Another 50 years would elapse before the last, stubborn Spanish farmers attempting to dry-farm wheat had shifted to summer maize.

Readaptation of the orchard trees also proved to be tricky. Spells of warm weather, punctuated by sudden and recurrent frosts during the blooming season rendered plum, cherry, and olive trees unproductive, and limited pear, fig, apple, pomegranate, and grape to slightly lower and warmer elevations. Only quince, and especially clingstone peach were sufficiently hardy to do well in the *tierra fria,* while grapes were able to penetrate the colder interior only after grafting on indigenous vinestocks. Even so, Sevillian grapes produced poor wines and were exclusively used for the table. The limited references to specific horticultural plants also suggested problems. The Mediterranean condiments probably could not compete against indigenous spices for the Spanish palate, and eventually only survived as medicinal plants. Most vegetables remained uncommon and many of these eventually disappeared from the menu. Spanish outfield legumes such as fava bean and chickpea were reduced to house or monastery gardens, presumably due to the appeal of indigenous phaseolus beans (*frijoles*). Fodder crops were initially limited to barley, but later included alfalfa. Flax could not compete with cotton. The resulting agrosystem retained its Mediterranean cast (Table 1–1), but it was impoverished, since its horticultural component was greatly weakened, and it lacked wine or olive oil. Irrigation also favored soft wheat cultivars (*candeal*) at the expense of traditional, hard or *durum* wheat. In effect, this agrosystem closely resembled the modified Mediterranean version that was typical of northwestern Europe. The absence of a milking tradition in Mesoamerica meant that goat and sheep milk products were unavailable, since farm labor was largely relegated to Indians. Thus, lard or tallow, rather than butter or olive oil, provided the obligatory cooking fats for Spanish cuisine. Only during the course of the 17th century were some dairy cattle bred to produce cheese.

## The Andean Highlands

When Pizarro invaded Peru in 1531, he apparently did not bring seed stocks. The first wheat kernels had to be gleaned from a barrel of rice in 1535, to be nurtured until the crop became large enough to justify gristmills 5 years later. Grape became available in 1551, and olive were first introduced to Lima in 1560 and Quito in 1573, while freestone peach first appeared on the marketplace a little before 1609. Cherries were only tested in Chile and Peru during the 1630s. Various flowers, condiments, and ornamental shrubs also were brought in late, roses in 1552, several others about 1580. This is a pattern of diffusion different from that evident for Hispaniola, Mexico, and Caracas, suggesting a gradual accretion due to individual initiatives rather than a systematic introduction. Nonetheless, these Spanish plants subsequently dispersed fairly rapidly from Lima along the length of the Andean valley systems, to Colombia and Bolivia. By 1570, distinctive agricultural nodes had begun to emerge around widely separated Spanish towns in the mountains and, ironically, the largest diversity of Mediterranean garden plants and condiments in the New World was found there.

The Spanish colonial centers of the Andean South America were comparatively aggressive in their efforts at hispanization of the agricultural realm, with both lay and clerical agents attempting to force the Indians to incorporate new plants, animals, and technology (Gade, 1992). Unlike highland Mexico, the Spanish house-garden tradition remained strong, and was diluted little by indigenous vegetables or spices (Table 1–1). In 1630, the flower displays or *rosales* of five towns were singled out for admiration, all of them colonized via Lima: Bogotá, Quito, Arequipa (Peru), Sucre (Bolivia), and Córdoba (Argentina). By contrast, Spaniards in Mexico were apparently overwhelmed by the panoply of indigenous flowers.

Wheat competed well with native grains in the Andes, and not just on colonial estates, but rye found little favor and millets are never mentioned. Mediterranean livestock did equally well, and a minor industry of cured hams, bacon, and sheep cheese developed among the Indians, providing Spanish tables with familiar animal products. Only the orchard crops were limited in their diversity (Table 1–1), metaphorically confused by the lack of thermal seasons. But even so, wines were successfully produced in the warmer Andean valleys of Bolivia. In short, the Mediterranean agrosystem was surprisingly successful in these tropical highlands, preserving most of the basic traits in a form analogous to that of the northern Meseta in Spain.

## Temperate Lowland Environments

The best ecological match for the Mediterranean agrosystem was in the coastal deserts of Peru and the semiarid, winter-rainfall zone of central Chile. Irrigated landscapes developed there on a commercial scale. With few surviving Indians, African, or Indian slave-labor had to be imported to tend to extensive tracts of wheat, alfalfa, vineyards, and olive groves during the early 1600s. Local olive oil was thought to be of better quality than that from Sevilla, and grape cultivars produced many different vintages in considerable quantity, so much so that a wineskin industry developed, based on goat leather. In Peru, the lack of natural pastures required other fodder for horses, namely green wheat, alfalfa, barley, and maize shucks. This is the one strictly Mediterranean agrosystem to emerge in the New World (Table 1–1), although it only came together several generations after the conquest.

Southern Chile was cooler and much wetter, so that northern Spanish fruit trees thrived there. Across the Andes, in northern Argentina and Paraguay, the climate was quite warm and marked by long, wet summers and intermediate latitudes. A modified, Mediterranean agrosystem developed (Table 1–1) relatively late, and new seeds or plantings were introduced well into the 1600s.

## DISCUSSION

In retrospect, the first 30 years were the most difficult in terms of ecological adjustment. Efforts to transplant Spanish agro-strategies to the Gulf-Caribbean tropics were a patent failure. But, subsequently there was a qualified success in highland Mexico, where the Spanish agrosystem had to compete with a versatile and fine-tuned indigenous agricultural package that had many attractive components. In South America, the Old World agrosystem came together much later, as a result of faulty organization; but it then proved unexpectedly tenacious and competitive, even as some of the orchard crops had to be abandoned in unsuitable environments. Interestingly, many of the introductions were only made once, so that pomegranate in Mexico was notoriously small, but good; or pear in South America, hard and tiny; some areas received several cultivars of one fruit, for example grape, peach, apple, and pear in Peru, while others only had a single, successful strain, such as quince and pear in Mexico. Thus, the accidental introductions also left permanent marks, at least during the first two centuries.

Other unpredictable aspects to the successful introduction of Old World plants were documented, namely the selection of immigrants. Less than one-half came from small or rural communities and few were farmers; those that were farmers came overwhelmingly from southwestern or western Spain (Boyd-Bowman, 1976), where few kept irrigated gardens or fruit orchards. The lack of familiarity with or subsequent interest in rye, oat, millet, spelt wheat, sorghum, and cowpea, or fruit and nut trees such as medlar, carob, almond, hazelnut, walnut, and chestnut played a significant role in their failure during at least the first century of transfer. The local impoverishment of the repertoire of Mediterranean spices also can be attributed in part to the backgrounds of immigrant communities aggregating in often isolated New World settlements. Information about the selection, transplanting, grafting, and pruning of Old World orchard crops was deficient, techniques quite unfamiliar to the indigenous peoples. Some reports attribute the failure of particular fruit trees in the new environment to a lack of qualified personnel, and Moreno Toscano (1968) argued that monks steeped in the old monastic garden culture were critical in propagating knowledge about new plants.

On the other hand, certain mechanisms favored the transoceanic transfer of certain plants. One such factor was the standard port-of-call of outbound ships from Spain on the Canary Islands, with their connections to the West African trade and to slave-worked sugar plantations on Madeira. That factor facilitated the transfer of tropical crops such as sugar, indigo, ginger, coffee, and sorghum, or trees such as the banana, coconut, and the new, sweet-orange hybrids from India. But in the end, of course, the bottom line was a suitable ecological and economic niche in the New World.

The Mediterranean agrosystem was tightly interdigitated with a livestock component (Butzer, 1988b) that took on added prominence in the New World (Butzer & Butzer, 1995). Cattle, probably derived from the Andalusian longhorns of the estuarine marshes below Sevilla, did unexpectedly well in almost all New World environments. They became the focus of the Spanish rural economy in vast areas outside of the several agricultural heartlands, leading to a prominent dietary role of beef among both colonists and Indians that had no precedent in Spain. Horses remained important for warfare and prestige, especially the breeding of mules (*Equus mulus*) for transport in the rugged terrain of the New World colonies. Their upkeep required considerable fodder, a need that was met differently in different areas.

Sheep found a niche in the tropical montane zone and especially in several semiarid areas that matched their ecological requirements fairly closely. As a result, in Mexico, sheep transhumance on several scales, analogous to that in Spain, became a significant economic feature, supplying a growing wool industry and providing meat for urban markets. Herds of sheep were managed by seasonal migration of 250 km or more by the 1580s and up to 800 km by the 1640s. That mobility reduced pressures on dry-season pastures, similar to livestock management in Spain, and helped explain the lack of evidence for soil erosion until the late 18th century, despite an intrusive biomass of some six to eight million sheep in Mexico.

Finally, commercial crops provided a critical alternative thrust for Spanish colonists in wet tropical environments. But labor and capital were always in short supply, transportation costs were high, and maritime traffic was widely spaced during the year and was seriously threatened by French and British pirates. African slaves were expensive, since Spain purchased them from middlemen, after the supply of Indian forced labor ran out. But a full-scale plantation economy did not develop. New World crops such as cacao, cotton, and tobacco, or Old World sugar, coffee, spices, and dyes were sometimes grown directly by the indigenous people, or more generally were cultivated on small Spanish estates. The British, French, Dutch, and Portuguese brought the sugar plantation system to its zenith, beginning during the mid-1600s (Curtin, 1990).

The ecological parameters, environmental resources, and indigenous cultural contexts of the different settlement centers in the Spanish New World favored some subsistence activities over others, offering sets of opportunities and generalized constraints. Where these differed fundamentally from those of Spain, a corresponding contraction of the traditional niche was paralleled by expansion into new ones. Even in the most suitable biophysical and cultural environments, the Spanish agrosystem had to be modified, with new seasonal strategies or the cultural substitution of indigenous crops. Agro-ecological readaptation, therefore, brought into play important forces for selection, divergence, and simplification of Spanish subsistence strategies in the New World (Butzer, 1992c).

The picture in French and British North America was in some ways similar (Cronon, 1983; Harris & Warkentin, 1974; Jordan & Kaups, 1989). Winter wheat could not be grown in Québec or New England, eliminating triple rotation, which was only established in the Swiss–German settlement region of southeastern Pennsylvania. Further south, plantation agriculture dominated in the tidewater lowlands, while in the back-country, the Scots–Irish colonists reverted to slash-and-burn and hoe agriculture as they moved westward. Pioneer agriculture was greatly simplified from its Old World models. By the time the land was fully colonized and land-use practices had reintensified, the original agrosystem had been revised in many of its details, including management of and attitudes to resources (Butzer, 1992b).

## INDIGENOUS AGROSYSTEMS AND BIOTIC EXCHANGE

Diffusion of information was a fundamental part of the Columbian Encounter, but simple lists of plants or animals transferred from one hemisphere to another convey little information. They also do injustice to the complexity of ecological adaptation and cultural screening, as potential cultivars were accepted or rejected.

The Spaniards encountered resilient civilizations in the highlands of Mesoamerica and the Central Andes, bringing their own expansive agrosystem into direct competition with alternative methods of subsistence that reflected divergent biogeographical and coevolutionary histories. The results were surprisingly complex.

In the Central Andes, the indigenous economy was based on potato, maize, and several minor grains. During the century after the Spanish Conquest, the indigenous peoples successfully incorporated many elements of the Spanish agrosystem, without radically changing their own management strategies and seasonal scheduling across several montane ecozones (Gade, 1992; Knapp, 1991). Wheat, barley, broad bean, and a number of condiments were evaluated and incorporated. The Mediterranean fruit trees did not do well, but Old World cooking banana and orange were very successful at lower elevations. Spanish livestock offered greater subsistence security and filled a larger potential niche than did the plants, since they provided food with relatively little work, or facilitated plowing and transport. Sheep offered meat and sometimes milk, while their wool was ideal for native textiles. Goats proved to be versatile grazers on steep slopes, just as pigs became waste processors in the villages. Spanish chickens were sturdy and good producers of eggs, displacing the domesticated Muscovy duck. Adoption of the Andalusian plow favored collective ownership of a plow team and plowshare, leading to open-field cultivation of crops.

In this region, then, the indigenous agrosystem proved very porous, as both ideas and material traits were adopted to reduce subsistence risk, and to offer a broader and more versatile diet (Gade, 1992). Although Spanish traditions were simplified and recombined within the Inca agrosystem (Table 1–2), wheat was adopted as a new staple.

In Mexico, the picture was different. The basic indigenous agrosystem extended from western Mexico to Nicaragua, crossing many linguistic groups. It was anchored on maize, frijol beans, and squash, emphasizing species of *calabaza* that yielded large seeds or delicate flowers used as potherbs. Grain amaranths also were important in the cooler highlands, while oil seeds were provided by *chía* (see Appendix), compared by the Spaniards to sesame (*alpiste*). Chili pepper and tomato represented the best known examples of a broader range of condiments that included a heterogeneous group of greens known as *quelites*, many

Table 1–2. Indigenous Agro-Strategies in different New World Environments before 1650 (representative crops are listed, in order of importance).

Highland Mexico (partly irrigated)

Grains and Pulses: Maize, frijol bean, chía, grain amaranth, with commercial wheat† locally

Vegetables and Condiments: Chili, squash, lettuce,† radish,† quelite, cabbage,† onion†

Fruits: Peach,† tuna, capulín cherriy, quince,† fig,† pear,† apple,† pomegranate,† apricot†

Livestock: Chickens,† turkeys, with increasing pigs,† sheep,† and goats†

Other: *Agave* sp. (Maguey/henequen), cotton, cochineal

Lowlands and Higher Valleys, Mexico and Central America (partly irrigated)

Grains and Pulses: Maize, frijol bean, chía

Vegetables and Condiments: Squash, chili, quelites, melon,† lettuce,† cabbage,† radish,†

Fruit trees: Citrus,† banana,† guava, avocado, sapote, capulín cherry, anona, peach†

Livestock: Chickens,† pigs†

Other: Sugar,† *Agave* sp., cotton, cacao, indigo†

Andean Highlands (partly irrigated)

Grains and Pulses: Maize, frijol bean, wheat,† barley,† grain amaranth, quinoa, fava bean†

Vegetables and Tubers: Potato, sweet potato, cabbage,† lettuce,† pepper

Fruit trees: Guava, sapote, avocado, capulín cherry, orange,† peach,† quince,† fig,† pomegranate†

Livestock: Llama, chickens,† sheep,† pigs,† mules/donkeys†

Humid, Tropical Andean Valleys and Perimeter

Field Crops: Cassava, maize, rice†

House Gardens: Sweet potato, frijol bean, peanut

Fruit trees: Guava, sapote, avocado, banana, † citrus, † cacao

Livestock: Chickens, † pigs†

† Indicates Old World introduction.

of which were found as commensal weeds in indigenous gardens. These basics never lost their central role, nor did the associated techniques of bed preparation, planting, and polycropping. Instead, the agrosystem showed considerable flexibility to new orchard crops, and to a more limited degree, garden vegetables, as can be discerned from the detailed information base of the *relaciones* of about 1580[2].

Indigenous arboriculture had, in fact, been quite informal, so much so that the Spaniards were unable to categorize native stands of fruit trees as orchards, and commonly believed that they were wild. Sometimes this was true, as in the case of the mesquite tree, used for pods that provided flour, fructose, and an alcoholic base. Others, such as the tuna or prickly pear, did not resemble a tree, but were apparently planted in orchard-like arrangements. Some tunas were wild, but many were cultivated, not only including great genetic diversity, but also cared for with distinctive micro-managed techniques (Colunga et al., 1986). Finally, the magueys, were genetically selected and diversified through an age-old, coevolutionary relationship to provide fibers, alcoholic drinks, or food (Bye,

[2] Compiled by local magistrates with information from indigenous informants, these reports are surprisingly good as traditional food sources, even though there may be a tendency to overemphasize Old World crops in some. The primary problem comes from taxonomic ambiguities, in that indigenous folk taxonomies commonly grouped unrelated cultivars according to visible similarities or the uses of their key products.

1993). A henequen plantation did not recall an orchard, but its plants were harvested much like trees, fitting no Old World category. Cochineal, a red dye produced by insects colonizing certain kinds of magueys, was long thought to be a plant product by many Europeans.

More evident fruit trees, like the capulín cherry or avocado of the high country, or tropical forms such as the guava (*guayabo*), anona, or the sapotes (comprising several families), were recognized by Europeans for their fruits, few of which looked or tasted familiar; but when planted or concentrated around settlements through accidental human dissemination, in seemingly random fashion, Europeans thought they were wild. In fact, planting and a measure of informal selection were common, but indigenous farmers believed in polycropping and pursued no esthetic goals for ornamental arrangements, in contrast to the Mediterranean farmer. Pruning and grafting also were unknown. What the immigrants could not appreciate was that similar informal tending, cultivation, or selection of nut trees had still been commonplace in the Mediterranean world during Classical times.

The evidence suggests that the indigenous peoples of Mexico were impressed by Spanish arboriculture, which by 1580 had become a new component of the native agrosystem (Table 1–2). A collection of wills and plans of house-complexes from one contemporary indigenous town confirmed that Mediterranean orchard trees had found a prominent niche both as fruit sources and ornamentals. Even today in indigenous areas of Mexico, peach and apple are planted with regular spacing, while capulín cherry will be hidden among the shrubbery. The Spanish term for peach, fig, and pear had found their way as loan words into Nahuatl by the 1570s (Lockhart, 1992, p. 289–291), and a tree, its name, and its proper space commonly went hand in hand.

At tropical or subtropical elevations in Mexico, citrus fruits and banana (especially the starchy, cooking hybrids known as plantains) became the most popular new fruit trees, in lieu of traditional Mediterranean species that required cool winters. The citrus group included the citron tree, known in Classical times; lime, lemon, grapefruit, and sour orange (mainly ornamentals), introduced to Spain under Islamic dominion; and sweet orange, disseminated in the Mediterranean world during the late Middle Ages or even after 1500 via the Portuguese India trade. Not generally familiar in southwestern Spain, they seemingly came to the New World as an afterthought, receiving little interest from Spaniards, but they were quickly adopted by indigenous peoples. Bananas were marginally known in a few parts of Spain, but primarily came to Hispaniola from Africa via the Canaries. Unlike Oviedo, most Spanish reporters in the *relaciones* no longer understood that banana had been introduced from the Old World, grouping them among native fruits in almost all cases; some even believed that citrus and sugarcane were New World plants. Consequently, neither citrus nor banana came with European associations of proper esthetics, and they were mixed in among cosmopolitan native tree plantings, and even went feral in adjacent forests at some locations.

As a group, the Old World fruit trees substantially expanded the role of arboriculture in Mexico, as ready sources of fructose, vitamins, or starches. By comparison, Mediterranean contributions to outfield and garden crops were less important. Wheat was grown in increasing quantity to meet the market demand of Spanish settlements, but was used little by indigenous communities. Lettuce, radish, and cabbage were broadly successful, both in the highlands and lowlands, presumably because they increased the variety of indigenous gardens, while melon were commonplace in tropical settings. The Mediterranean bottle gourd differed from its New World at a subspecific level only, and found some acceptance. Some interest in onion, garlic, parsley, mint, and coriander was documented. But, in general, Old World condiments could not compete with the culinary versatility and visual appeal of *capsicum* peppers (see Pickersgill, 1988) and survived mainly in the vast body of indigenous pharmacopoeia (Esteyneffer, 1978; Hassig, 1989). Spanish favorites such as broad bean and chickpea were initially grown for market, and subsequently produced on a commercial scale during the 1700s; chickpea (*garbanzos*) ultimately left their imprint on local cuisine.

Indigenous response to Spanish animal domesticates was mixed. Chickens were the one exception, being immediately seen as a good complement to or substitute for domesticated turkeys or other, semidomesticated fowl. Pigs promptly gained acceptance in most areas, but were shunned in others, and never gained commercial importance in Colonial times, in contrast to Peru. Similarly, some Indian communities acquired large flocks of sheep or herds of goats by the late 1500s, while others kept none at all. Illegal butcheries for stolen cattle provided cheap beef to indigenous villages, and legal provisions for Indian miners included beef; however, Indians rarely raised cattle other than for plow animals, in areas where wheat growing required outfield plowing.

Overall, Mexican Indian groups displayed great flexibility in responding to new agricultural, nutritional, and economic opportunities. But they were unwilling to change their staple diet, cuisine, or work methods and, when the Colonial era was over, Mexican elite cuisine once more became indigenized in all but the largest cities. Wheat is still grown on a large scale in a few districts of Mexico, but, ironically, is now commonly used as a fodder crop.

That in no way diminishes the importance of the Old World introductions, which filled both dietary and seasonal niches, to reduce subsistence risk. Almost the whole range of Mediterranean plants, adapted to winter growth and summer drought, were planted (or transplanted) during the winter half-year and many could, with some irrigation, be harvested at the time that photosynthesis of most New World plants only began (Hernández, 1993). Some of the key fruit trees could, with minimal irrigation, thrive on sites far too dry for avocado, guava, or sapote. Small wonder that the Old World introductions increased the repertoire of standard indigenous crop plants by roughly one-half, both in the temperate and tropical zones of Mexico (Table 1–2).

The high civilizations of the Andes and Mexico responded to new cultivars and animal domesticates in complex and different ways. The Andean peoples accepted a new staple, but rejected most of the fruit trees, while their Mesoamerican counterparts retained the old staples, but accepted the fruit trees. Indeed, both agrosystems became hybridized (Table 1–2), even though ecological and economic accommodation did not imply a change of the underlying cultural values, despite the traumatic experience of catastrophic population loss. Similar patterns were visible among the Indians of the eastern USA, who adapted and readapted apple, peach, potato, watermelon, as well as pigs and, locally, cattle within their agrosystem. Taking place well before foreign conquest, the wide acceptance of Old World germplasm contradicts the idea of ecological imperialism, and puts the whole transfer into proper perspective, as an overwhelmingly voluntary process.

Transoceanic diffusion of crops after 1492 was, of course, a two-way street (Fig. 1–4 and 1–5). Within decades of the Columbian voyages, plant-specialists in Europe were examining a diversity of New World crops with great interest. But actual acceptance was slow and qualified (Casanova & Bellinger, 1988; Foster & Cordell, 1991; Hawkes, 1990; Hawkes & Francisco-Ortega, 1992). Maize displaced millets, becoming a major fodder crop in southern and eastern Europe; but it was never accepted as a dietary item in western Europe. Tobacco and imported cacao had more immediate success, which comes as no surprise. Sunflower was accepted slowly as a source of oils, and then began to gain popularity for the chewiness of its seeds. Tomato, after initial resistance, became the highlight of Italian cuisine. Only the potato eventually emerged as a real staple in Europe, as its productivity and high caloric yield became apparent to poor peasants, first in Ireland, then in Britain and on the Continent. The potato contributed significantly to European population growth (Hobhouse, 1985; Langer, 1975).

European colonists in the New World accepted the new foods or condiments far more rapidly than did their folks back home. By the 1580s, Spaniards in smaller provincial centers of Mexico had been forced to turn to maize because wheat was unavailable. Maize also became a minor staple in British North America, especially in the South. But the greatest success for New World cultivars was in the Old World tropics and subtropics (Simoons, 1990). Maize emerged as a key staple in West and Southern Africa, and a minor staple in India and parts of China. Cassava or manioc, sweet potato, and peanut dispersed across Africa

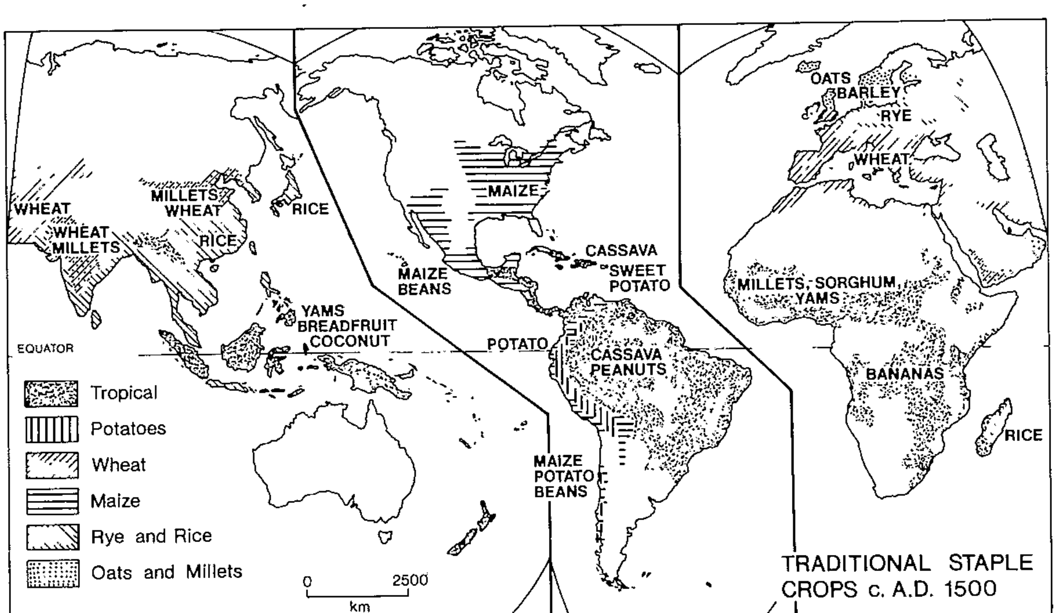


Fig. 1–4. Traditional Staple Crops in about 1500. Based in part on Simmonds (1976) and Sauer (1993).

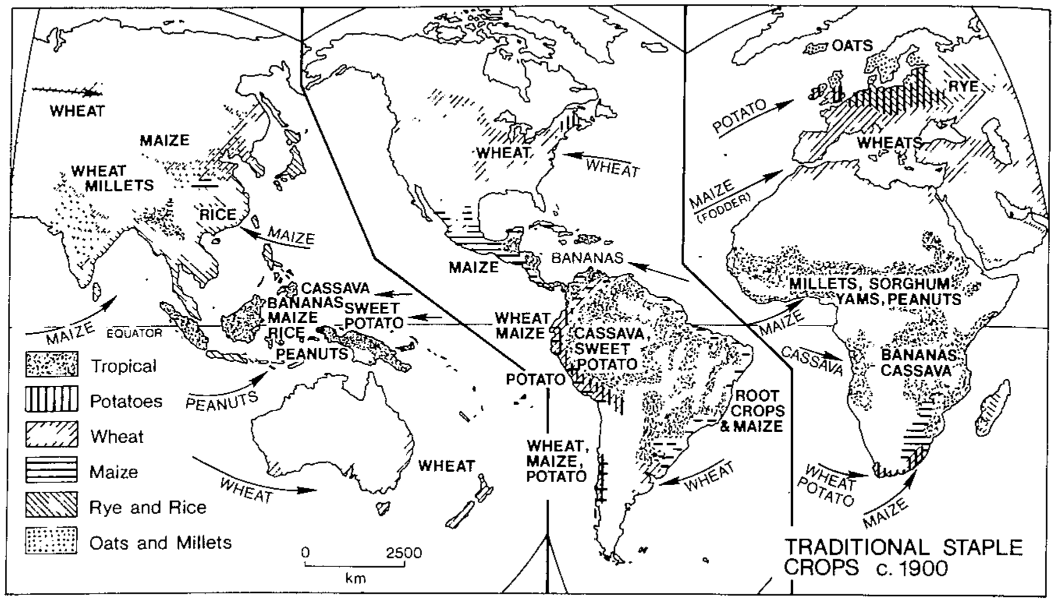


Fig. 1–5. Traditional Staple Crops in about 1900. Based in part on Simmonds (1976), Sauer (1993), and Simoons (1990).

or via the Manila galleons from Mexico to Southeast Africa, diversifying diets and reducing subsistence risk. Pineapple and vanilla were welcomed all over, and quinine served as a malaria remedy.

This return flow of crops, representing millennia of New World agroeconomic experience, was of immense importance, matching in many ways the success of modified versions of the Mediterranean agrosystem in the Americas (Fig. 1–5). This aspect of the Columbian Exchange, representing a global migration of food crops, was not only benign, but generally improved the quality of human life.

The final section of this chapter turns to a different, but closely related theme, the controversial impact of European agrotechnology on the environments of the New World.

## MYTHS AND MISUNDERSTANDINGS ABOUT ECOLOGICAL HARMONY AND DEVASTATION

The polemic surrounding the Encounter has revived the old myth of the American Noble Savage, living in a primitive Eden. The Native American has become a Primeval Ecologist, "transparent" in the landscape, "living as a natural element of the ecosphere" (Shetler, 1991, p. 226). This was a myth, as the evidence showed.

At the time of Contact, the so-called New World had a population upward of 50 million, with settlement densities in several regions comparable to those of the early 20th century (Denevan, 1992a). In some areas, such as the Amazon Basin, population densities were greater than they were only a decade before. Maintaining such population levels required high and sustained agricultural yields, that in turn implied considerable landscape modification (Denevan, 1992b; Doolittle, 1992; Whitmore & Turner, 1992). Ethnohistorical and physical evidence demonstrated that complex and controlled, agricultural landscapes dominated much of Mesoamerica and the Andean World, complementing the more familiar image of Precolumbian cities (Turner & Butzer, 1992). Even in the eastern woodlands of the USA, agriculture was a prominent feature that left a permanent imprint.

Native Americans did not have a magical recipe to feed themselves without humanizing and modifying their environment. Several lines of biotic and soil evidence proved this point. Pollen and limnological records from several parts of Mexico showed that periods of high, prehispanic population density led not only to deforestation, but also to weed explosions, soil erosion, and ecological degradation (González & Fuentes, 1980; Metcalfe et al., 1989; O'Hara et al., 1993). The same was true in Central America, where topsoil and nutrients were washed rapidly into lakes near Classic Maya sites (Rice et al., 1985; Vaughan et al., 1985), while paleoecological evidence documented substantial deforestation in Honduras and Panama millennia before 1492 (Abrams & Rue, 1988; Piperno et al., 1991). The landscapes described from both North and South America by early explorers commonly were open, and exploited by large numbers of indigenous people, eking out livelihoods. In many cases, Indian *de*population after 1492 led to forest regeneration and greater biodiversity, so that there was more wilderness in 1700 or 1750 than there was in 1500 (Denevan, 1992b).

Much was made of the different land ethics incorporated into the values of different culture systems (MacLeod, 1992). Since the influential writings of Lynn White, an exploitative ethic was attributed fashionably, but questionably, to the Judeo-Christian tradition that underlies European civilization (Kay, 1989). Similarly, it now is politically correct to interpret Native American attitudes to resources and nature as highly conservationist, imbued with a reverence for the earth and all living things. The most explicit testimony for conservation and landscape, the proverbial working with nature, is Chinese. Yet Yi-Fu Tuan (1968), as a sympathetic investigator, could find no evidence that Chinese land use over the centuries was effectively controlled by reverence for the natural world. When population densities required continuous cultivation of indifferent soils, without fallow, survival took priority over ideals. That inference was particularly relevant for central Mexico, where population expanded at a steady rate of 1% per year for fully 150 years prior to the arrival of Cortés (Butzer, 1992d; Williams, 1989). In the contemporary world, that would be a certain recipe for ecological disaster. In short, the pristine myth was grossly simplistic. It also was pejorative to Native Americans, by reinforcing a stereotype of technologically primitive aborigines who blended into the forest.

Simplistic assumptions about what people will do when confronted with subsistence stress should be avoided. The land ethics of different cultures were important, particularly when they happened to be explicitly incorporated into the philosophical or cosmological realm. But such precepts also may be transmitted implicitly, in more mundane contexts, such as the concept of good husbandry that pervaded Graeco-Roman and early Medieval agronomic writings (Butzer, 1993). Judgment must therefore be based on a careful assessment of performance.

What about the other side of this New Age slogan, namely the much-touted claim of a Devastated Colonial Landscape, destroyed by ruthless, materialistic European settlers, asserting their claimed dominion over nature (e.g., Sale 1990)?

To begin, all environmental change after 1492 cannot be lumped under one hat. A global Industrial Revolution intervened between the 20th century and the landing at Plymouth Rock, while from 1776 to 1821, the New World colonies moved to independence. The parameters and perspectives of what transpired after 1776 were different, reflecting a spate of technological innovations, accelerating demand for distant raw materials, rapid population growth, and a more complex global network that integrated raw materials, industrial production, and markets. Different technologies, motives, and perceptions highlighted the European settlement experience before the mid-1700s, than those characterizing the expansion of the several, new American societies after independence.

Precisely that point makes examination of the question difficult. To determine whether European settlers in Colonial times devastated the landscape will require many more local or regional studies of vegetation and soil histories, as well as of land use and management (Butzer, 1992b). The available case studies, however, suggest that the Devastated Colonial Landscape also was a myth.

Hydrological change, soil erosion, and large-scale deforestation have, thus far, only been properly documented for the period after 1750 or even after 1800 (e.g., Metcalfe et al., 1989; Butzer, 1992d). In Central Mexico, accelerated runoff and severe flooding after 1750 was a consequence of expanding mining activity, locally, and more generally, the increasing shortage of land (Butzer & Butzer, 1995). In the American South, soil devastation accompanied the expansion of cotton from the 1780s to 1860 (Trimble, 1974), in response to demand for raw materials by the textile industries of New England and Britain. In the upper Midwest, the clear-cuttings of the 1830s supplied timber for the iron-making furnaces of Pennsylvania. This does not preclude future demonstration that some areas were degraded at an early date, nor does it address more subtle changes, such as reduced diversity or species replacement in the tree or ground cover, but these changes can only be detected by fine-grained methodologies that are not yet available. As it now stands, various lines of evidence should caution against making assumptions about European land use practices.

The empirical evidence, as opposed to the undocumented claims of Kirkpatrick Sale (1990), for example, showed that European land use has been overwhelmingly conservationist since prehistoric times, despite local or regional crises in environmental stability. Agricultural productivity in the Mediterranean Basin has been sustained through >6000 years of farming and pastoral land use. Pollen evidence showed that after distinctive, Neolithic-to-early Bronze Age experimentation, the Mediterranean woodlands were more or less continuously managed as an artificial ecosystem that, on the whole, was sustainable (Butzer, 1996; Stevenson & Harrison, 1992; González Bernáldez, 1994; Butzer & Butzer, 1995). Cumulative damage to the soil mantle was no greater than in northern Europe, as studies of alluvial sediments showed. But the highly mobile pastoral sector of the economy continued to reduce subsistence risk, while providing the manure essential to sustained crop productivity.

The acute risk to the Mediterranean ecosystem today has nothing to do with Bronze Age goats or Medieval sheep, but to water contamination by industry and sewage disposal. Livestock can be very destructive to the environment when poorly managed. But the mounting biophysical evidence showed that, historically, equilibrium management was the rule, rather than the exception (Stevenson & Harrison, 1992). More than 200 generations of sedentary peoples were thereby sustained, quite successfully. The real questions are: when, where, and why was conservationist European agriculture abandoned in the New World?

The history of New World biota and soils, in relation to land use and human modification, requires a new round of attention, particularly in North America. With complex histories of deforestation and regeneration, changing plant successions and biodiversity, or the surprising impact of fire and catastrophic storms, ecologists are beginning to appreciate that empirical environmental histories are critical in order to evaluate management and conservation strategies. Simplistic myths, however appealing, can only muddy the waters at a time when critical conservationist decisions must be made for the future.

These internested historical, cultural, and environmental questions transcend the Encounter, and have interdisciplinary implications for contemporary ecology. What exactly do we mean by virgin forests? The Harvard Forest Project demonstrated complete forest regeneration in about 150 years, although not all the dominants are back in strength, nor in the same rank order as those of the early 1700s (Schoonmaker & Foster, 1991). The rain forest of northern Guatemala was eradicated about 2000 years ago, but regenerated and recovered its original species diversity within two to five centuries after the prehistoric Maya population crash (Vaughan et al., 1985). American forests protected from fire today change their dominants with respect to those of 1000 or 1500 years ago (Heinselman, 1981). What are the implications of such discoveries for concepts such as ecological recovery, succession, and climax? Problems of this kind evidently plagued the management of Yellowstone National Park in recent years.

More studies are needed to integrate paleoecological research with land-use histories. Such work will be rewarding and have many applications. Furthermore, field observations, laboratory analyses, and archival documentation, in combination, can generate processual understanding at the local or regional level (Butzer, 1992b). Such detailed environmental histories require sustained study, and cannot be proclaimed from a hilltop by the sweep of a hand. Hopefully, the fanfare of the continuing Columbian controversy will convince more researchers to invest their time and efforts in this direction. It is high time for the many interlinked disciplines interested in the environment and in food to shift to larger geographical and historical scales of investigation. These are essential if global environmental change is to be brought into the compass of resource management.

## ACKNOWLEDGMENTS

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# APPENDIX

## Common and Scientific Names in the Columbian Exchange

Names of Old World Plants representative of 16th Century

| Common | Scientific |
|---|---|
| Alfalfa | *Medicago sativa* L. |
| Anise | *Pimpinela anisum* L. |
| Artichoke | *Cynara scolymus* L. |
| Barley | *Hordeum vulgare* L. |
| Beet, Leaf | *Beta vulgaris* L. var. *cicla* |
| Borage | *Borago officinalis* L. |
| Cabbage (Savoy, Kale) | *Brassica oleracea* L. |
| Camomile | *Anthemis nobilis* L. |
| Capers | *Capparis* spinosa L. |
| Caraway | *Carum carvi* L. |
| Carrot | *Daucus carota* L. |
| Celery | *Apium graveolens* L. |
| Chickpea (Garbanzo) | *Cicer arietinum* L. |
| Chickory | *Cichorium intybus* L. |
| Coffee | *Coffea* sp. |
| Coriander | *Coriandrum sativus* L. |
| Cowpea (formerly Alúbias) | *Vigna unguiculata* (L.) Walp. |
| Cress, Garden (Mastuerzo) | *Lepidium sativum* L. |
| Cucumber | *Cucumis sativus* L. |
| Dill | *Anethum graveolens* L. |
| Eggplant | *Solanum melongena* L. |
| Fava bean | *Vicia faba* L. |
| Fennel | *Phoeniculum vulgare* L. |
| Flax | *Linum usitatissimum* L. |
| Garlic | *Allium sativum* L. |
| Ginger | *Zingiber officinale* L. |
| Gourd, Bottle | *Lagenaria siceraria* (Molina) Standley |
| Grape | *Vitis vinifera* L. |
| Grass Pea (Chícharo) | *Lathyrus sativa* L. |
| Indigo | *Indigofera suffruticosa* Miller |
| Leek | *Allium porrum* L. |
| Lentil | *Lens culinaris* Medikus |
| Lettuce | *Lactuca sativa* L. |
| Lupine | *Lupinus* sp. |
| Melon | *Cucumis melo* L. |
| Millet | |
| Common | *Panicum miliaceum* L. |
| Foxtail | *Setaria italica* (L.) P. Beauv. |
| Mint | *Mentha spicata* L. |
| Mustard | *Brassica nigra* (L.) Koch |
| Oats | *Avena sativa* L. |
| Onion | *Allium cepa* L. |
| Oregano | *Origanum vulgare* L. |
| Parsley | *Petroselinum crispum* (Miller) Nyman |
| Parsnip | *Pastinaca sativa* L. |

| | |
|---|---|
| Pea, Garden | *Pisum sativum* L. |
| Pennyroyal (Poleo) | *Satureia brownei* (Sw.) Brig. |
| Radish | *Raphanus sativus* L. |
| Rice | *Oryza sativa* L. |
| Rose | *Rosa* sp. |
| Rye | *Secale cereale* L. |
| Sage | *Salvia officinalis* L. |
| Safflower (Cártamo) | *Carthamus tinctorius* L. |
| Safran | *Crocus sativus* L. |
| Sesame | *Sesamum indicum* L. |
| Sorghum, Grain | *Sorghum bicolor* (L.) Moench |
| Spinach | *Spinacia oleracea* L. |
| Sugar cane | *Saccharum officinarum* L. |
| Thyme | *Thymus vulgaris* L. |
| Trees | |
| Almond | *Prunus amygdalus* Batsch |
| Apple | *Malus pumila* Miller |
| Apricot | *Prunus armeniaca* L. |
| Banana | *Musa* sp. |
| Carob (Locust) | *Ceratonia siliqua* L. |
| Cherry | |
| Sweet (Cereza) | *Prunus avium* (L.) L. |
| Sour (Guinda) | *Prunus cerasus* L. |
| Chestnut, Sweet | *Castanea sativa* Miller |
| Citron | *Citrus medica* L. |
| Coconut | *Cocos nucifera* L. |
| Date palm | *Phoenix dactylifera* L. |
| Fig | *Ficus carica* L. |
| Grapefruit (Toronja) | *Citrus paradisii* Macfad. |
| Hazelnut | *Corylus avellana* L. |
| Lemon (Limón) | *Citrus limon* (L.) Burman f. and *C. aurantifolia* |
| Lime (Lima) | *Citrus aurantifolia* (Christm.) Swingle |
| Medlar | *Mespilus germanica* L. |
| Mulberry, white | *Morus albus* L. |
| Olive | *Olea europaea* L. |
| Orange | |
| Sweet | *Citrus sinensis* (L.) Osbeck |
| Sour | *Citrus aurantium* L. |
| Pear | *Pyrus communis* L. |
| Peach | *Prunus persica* (L.) Batsch |
| Plum | *Prunus domestica* L. |
| Pomegranate | *Punica granatum* L. |
| Quince | *Cydonia oblonga* Miller |
| Walnut, Persian | *Juglans regia* L. |
| Turnip (Nabo) | *Brassica campestris* L. |
| Watermelon | *Citrullus vulgaris* Schrader |
| Wheat | |
| Breadwheat (Soft) | *Triticum aestivum* L. em Thell |
| Hard wheat | *Triticum durum* Desf. |
| Spelt | *Triticum spelta* L. |
| Yam, Old World | *Dioscorea* sp. |