Agriculture and Biodiversity in Latin America in Historical Perspective

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Summary: Latin American is thought to be the world's most biodiverse region, but the number of species and the size of their populations is generally in sharp decline, as in most of the world. Conservation biologists consider agriculture to be the most important cause of biodiversity decline. Historical literature is rich in implications for conservation research and practice, but the literature and its insights are not well known to most who practice in the field. Here, a necessarily generalized overview of the historical literature of greatest value to conservation policy with regard to biodiversity corrects some frequent errors made by conservationists and raises a number of important but unanswered historical questions about the significance of agriculture for biodiversity conservation. These questions are ripe for research.

Keywords: biodiversity; Latin American agriculture; Columbian exchange; geography, agricultural technology; conservation policy; indigenous agriculture; export agriculture; agriculture and environment; landscape; anthropogenic landscapes; biodiversity and social organization

The biodiversity crisis in Latin America: current controversies.

The diversity of earth's plant and animal species is in sharp decline on all continents. Latin America is considered the most species diverse region on the planet, with 40-50% of the world's tropical forests, and a large variety of unique ecosystems ranging from coral reefs to extreme high alpine environments. Unfortunately, steep species decline in the region parallels global trends.[1] Historical research provides significant insights into attempts to reduce the loss of species in Latin America.

There is strong agreement that agriculture in Latin America and elsewhere, including habitat change connected to expansion of agricultural activities, is the single most important of the many factors leading to species decline and extinction. Rapid urban growth in species rich-areas is also considered among the most serious threats to biodiversity. The speed and magnitude of urban growth in Latin America since World War II is due in significant measure to the exodus of rural people to the city. In turn, the size and speed of this exodus is in large part a result of changes in agricultural technology and associated capital requirements that have tended to drive smallholders and day laborers out of the countryside while at the same time introducing intensive use of agrotoxins, reduced crop diversity, and biologically destructive large irrigation projects. Industrial agriculture significantly contributes to climate change that has already reduced species populations and is expected to be a major threat to species diversity in coming decades. Conservation policy meant to slow or reverse the loss of species must confront the implications of agriculture with respect to species survival but there is little consensus about what should be done. [2]

Some conservationists focus on the task of limiting the expansion of agriculture into wild habitats by creating "protected areas", while doing relatively little to question particular crop choices or production practices. "Modern" or "industrial" agriculture characterized by large field size, low crop diversity, severe reduction of wild diversity within cropping areas, and heavy reliance on synthetic pesticides and fertilizers, as well as abundant irrigation in many areas, is taken as a given, even though these characteristics all tend to reduce biodiversity on land and water inside and outside those areas devoted to crops. Many conservationists do not question the necessity of such practices in agriculture, while others maintain that a great deal could and ought

to be done to change what is grown and how it is cultivated, arguing that much of agriculture could be productive consistent with some significant amount of species protection and recovery.[3]

While there is strong agreement among those concerned with biodiversity protection that "protected areas," including parks, forest reserves, biosphere reserves, indigenous reserves, and other forms of legal restrictions should be expanded and strengthened, there is considerable confusion about what kinds of protection are most effective. In particular, there is a lack of clarity about the existence and significance of agriculture and other productive activities *within* protected areas.[4]

Much of this controversy was generated in the last two decades of the twentieth century and becomes more critical as the frontiers of agriculture have expanded rapidly within areas previously characterized by high biodiversity, especially in the humid tropics of Meso-America, the Amazon Basin, and the Brazilian *cerrado.* As modern agriculture has expanded in area and as it tends to progressively adopt technologies more threatening to species, science has provided increasingly strong evidence for legitimate concern with the survival of biodiversity. Concern for biodiversity has become culturally and politically stronger and more evident in academic circles and social movements.[5]

The pace of relevant change in land use has far outrun society's ability to limit species loss. While the sheer size and complexity of Latin America make it difficult to generalize from detailed knowledge and experience in any particular sub-region, the sense of urgency about needed actions makes it necessary to make some sense out of the diversity.

There is a tendency for conservationists to think of biological diversity in Latin America as having arisen out of such natural conditions as latitude, altitude, climate, and terrain. This is fair enough as a starting point, but is seriously misleading if the human history of the region,

beginning many millennia ago, is not taken into account. Among other things, it must be remembered that Latin America includes places where humans invented agriculture. It is also essential to realize that the human history of the region cannot be summarized simply in terms of the size and spread of human populations. The history of Latin America provides an especially good case study to show that it is not human presence alone that matters in shaping the biological landscape. As obvious as it may seem, it is frequently forgotten that there are many ways humans live within landscapes and change them. Cultures, technologies, and power relationships in culture are critical as influences on biodiversity. No one can hope to settle the many important issues raised by the history of agriculture and its impact on biodiversity in Latin America—historical research has raised as many questions as it has answered. It is possible and highly useful, however, to clarify and argue the importance of some well-known historical knowledge, especially because this knowledge has sometimes failed to penetrate the world of conservation experts and policy makers. At a minimum, this makes it possible to identify what some of the important questions are that beg for new research effort.[6]

Human population size does not determine species abundance: new technologies and social organization change the equation

The importance of historical knowledge—and, especially, the dangers of making assumptions without sufficient historical knowledge--has been highlighted by a study by British biologists who contend that the European conquest of the American territory led to a significant decline in global atmospheric carbon levels through reforestation of abandoned land in the Western Hemisphere. Having noticed a decline in atmospheric global carbon dioxide levels in the sixteenth and seventeenth centuries, the study authors looked for an explanation. They

believe they have found it in the decline of New World human populations in that period due to the massive human mortality among indigenous American peoples caused by the introduction of Old-World diseases to populations with no acquired resistance to these diseases. They have linked this human population decline to the chronological correlation of declining atmospheric carbon. From this correlation in time they have moved to an assertion of causation, arguing that population decline *caused* a significant decline in atmospheric carbon through abandonment of agricultural activities and subsequent reforestation of abandoned land. The formula is simple: large human populations must depend on agriculture and if populations decline, the area devoted to agricultural production declines and reforestation results, absorbing atmospheric carbon. Although the study authors do not do so because climate change, and not biodiversity, was their concern, it would be logical to deduce from this formula that the diversity and population size of wild species would also have increased from land abandonment and subsequent reforestation.[7]

The formula is certainly simple. It is almost certainly wrong. We do not know what may have caused a perceived decline in global temperatures in the seventeenth and eighteenth centuries, but it almost certainly was *not* a generalized reforestation due to population decline. Spanish and Portuguese brought new kinds of agriculture that used larger areas of land with far fewer people. The most important means by which they did this were the plow and the livestock they introduced to the New World. They also imported slaves to provide the labor they needed to realize their ambitions. All led to active use of land over much wider areas than practiced by native cultivators.

The usual result was very heavy damage done to land and forests, often to a degree that led to endemic poverty where relative prosperity had existed at higher population levels. Severely damaged soils meant that reforestation, where it might otherwise have been possible,

would be very slow and involve a smaller ensemble of tree species. Deforestation, grazing pressures, and European farming techniques often accelerated erosion and reduced the size and/or increased the depth of aquifers to a degree that created permanent deserts from previously lush forested and/or rich agricultural landscapes.[8]

The Columbian Exchange

Complicating our understanding of the impact of Europeans on the American landscape is what has come to be called *The Columbian Exchange*. An immense array of species was deliberately and accidentally introduced into the Americas, as American species moved into Europe. Along with species exchange came an exchange of ideas, technologies, culture, and societal arrangements. Ecological theory would strongly suggest that while this may have expanded the number of species present in the Americas, it also displaced or reduced the population size of native species and reduced the overall biological productivity of ecosystems, in ways we are still trying to fully understand.[9]

Contrasting purposes: labor, mines, markets, and landscapes

Colonial purposes: the fate of the land in a global economy of structured privilege

Legal and institutional changes in the control of labor and land under colonialism brought dramatic effects. In areas of high population densities, Spanish legal tools such as *encomienda, mita, repartimiento,* and *congregacíon* provided a legal framework for the dispossession and actual or virtual enslavement of native peoples, even where native land rights were nominally honored. Portuguese land law worked differently, but with similar results.[10]

Just as important, wherever possible, Europeans preferred to use land for the production of commodities for export to Europe, not for local food production. Spanish and Portuguese favored profitable export crop commodities like sugar.[11] They also raised large numbers of soil-

ravaging sheep for wool. Pigs and goats, raised largely for local consumption, also did more than their share of damage in indigenous farms and gardens previously free from such ravenous intruders.[12]

Commodities not raised directly for export were raised to supply mines that constituted the most important economic activities in many regions through much of the colonial period and later. Horses, mules, donkeys and oxen were in high demand for mining operations. Mines required immense amount of timber to shore up deep shafts and in the processing of raw ore. Mines also devasted large areas of farmland and forest by spreading toxins across the landscape and into lakes and rivers.[13]

The markets for minerals, like those for export agricultural commodities, were international and were not constrained by the size of indigenous populations nor by local needs, nor even by demand within the boundaries of the entire Western Hemisphere—the direct markets were in Europe, where population size was large and expanding over the long term. Further, the demand for silver came particularly from the insatiable desire for silver in China, with its large population and a regime that often insisted that payment of taxes be made in silver. Peruvian and Mexican mines provided the silver that traders used to acquire goods from China. Mines linked the degradation of soil, the exploitation of the labor of peasant farmers and imported slaves, and the clearing of forests all directly to Europe and China.[14]

Most agriculture for export markets and for mines was monocrop production with large regions devoted almost exclusively to the production of one or a very few crops. In many regions, including much of the Caribbean and the Atlantic Coast Forest region of Brazil, planters, following in the footsteps of loggers who harvested valuable timber, carried out the nearly complete destruction of previously biodiverse forests to plant sugar. It was common to

forbid slaves who worked sugar plantations from growing their own food for fear that food independence might lead to insubordination and rebellion. This led to even further simplification of the biological landscape and dependence on food imports often from other regions of Latin America. Sugar refining required stupendous quantities of firewood to fuel boilers, with the early exhaustion of on-site wood supplies requiring owners of sugar mills to reach for firewood far into forests and scrublands, sometimes hundreds of sometimes miles from the sugar fields themselves. Vast regions of very species-rich forests in the Caribbean, Brazil, Mexico and elsewhere were destroyed by the ambition of sugar planters and exporters. It would be difficult to overestimate the negative consequences for biodiversity.[15]

Grazing systems varied over the centuries of European colonization with markedly different impacts on biodiversity, but the initial impact of the importation of European grazing animals was almost certainly negative for forests and wild biodiversity. Grazing systems for beef cattle may have been less damaging than that of other livestock, as has been the case in many times and places. International demand for gold, silver, and other minerals determined the size of the market for local production of traction and pack animals and provisions for miners.[16]

Indigenous purposes and methods

In contrast, indigenous agriculture typically used a diverse array of inter-planted crops (crop species mixed within single planting areas), small field size, and incorporation of tree and perennial crops with annuals. The soil was little disturbed by digging sticks used to plant seeds in comparison to the damage done by European plows. In most regions, significant dependence on hunting and gathering complemented agriculture, helping to explain why, before and after Conquest, many indigenous communities fought hard to conserve forests. Where swidden required annual burning of forests, local knowledge specified how long fields should be used

until they were abandoned to reforestation. Areas cleared were strictly limited by an understanding that reforestation was vital to the continued productivity of the system.

In the indigenous world—where wheeled vehicles were unknown, draft animals were non-existent, and where pack animals were largely limited to the rugged ranges of the Andes—the limits on transportation meant that agriculture was keyed to meeting the diverse nutritional demands of local populations rather than monocrop production for international markets. The features of indigenous agriculture tended to create complex and biologically-rich landscapes.[17]

There were certainly exceptions. In some areas, indigenous systems depended on construction and maintenance of terraces and irrigation systems. Some of these systems created and even depended upon chronic soil erosion from deforested slopes. In the Mixteca of Oaxaca, for example, soil erosion had been incorporated into centuries of practice in a way that enriched the land of nobles with new nutrients at the expense of upland peasant farmlands; such systems were almost certainly prejudicial to biodiversity as they replaced upland oak and pine forests and forced peasants into desperate use of all available resources to maintain survival. Some have suggested that these systems were likely at the cusp of collapse at the time of Conquest. The arrival of European disease meant that sufficient labor to maintain the terraces was unavailable, and, in any case, the Spanish overlords did not adequately understand the system and at the same time demanded too much of it. Collapse led to a severe impoverishment of the region that persists to the present.[18] Similar processes occurred in the Andes where agriculture was exquisitely adapted to relatively high populations and the demanding conditions of high altitudes on the one hand, and the labor-intensive management of large-scale irrigation systems in lowland valleys, on the other. Population collapse, Spanish ignorance and inexperience, and the extreme

demands of a mining economy, that for a time was the principle motor of global economic expansion, led to massive damage to farmland, ecosystems, and local societies.[19]

These generalizations account for a great deal of the undoubted loss of forests and other biodiverse landscapes of the New World in the first three or four centuries after European conquest of Latin America. They demonstrate that there can be no assumed increase in forests nor in biodiversity as a result of indigenous population decline—scientists will have to look elsewhere to explain decreased carbon dioxide in the atmosphere. Indeed, what empirical evidence we have strongly supports a contrary hypothesis: European imperialism brought fatal disease that decreased native populations *while at the same time* introducing other changes that in general wreaked havoc on indigenous agricultural systems and existing forests and other wildlands. While there is evidence for significant reforestation in some areas with the combination of population collapse and economic depression in the latter half of the seventeenth century, deforestation continued in many areas during this period. It is also notable that in the late eighteenth century towards the end of the colonial period, colonial officials in New Spain (Mesoamerica) and other observers began to decry generalized deforestation, although a survey indicated that in some areas forest regrowth was considered a hazard and an indicator of economic decline. In New Spain, a Council on Forests recommended actions that in retrospect probably worsened the problem, again, at the expense of indigenous communities, but deforestation was recognized as a generalized problem requiring government action.[20] In Brazil, writers and royal officials began to argue that a growing crisis of deforestation was linked to the dependence of the economy on slavery.[21]

Unique and notable cases of agriculture and diversity

Although this alternate hypothesis is strongly supported by the evidence in those regions that have been carefully studied, it does not account for the complexities of change that occurred. The complex and varied nature of New World agriculture means that each region requires separate analysis that raises interesting and important issues. Here we discuss a select few.

Central Mexico and north: unique systems in the face of contrasting European purposes

Among these regions are the highlands of Mexico. Central highland Mexico was almost certainly the most densely settled area in the New World, peopled by the Aztecs, Toltecs, and people who had been politically and militarily subjugated by them. The Aztec capital, Tenochtitlan, was probably one of the most populous cities in the world in 1500, especially if one includes the neighboring Toltec city states. The expedition of Hernan Cortes to conquer central Mexico made it the earliest area of sustained and significant encounters of Europeans with Native Americans. Mexico's central highlands suffered a catastrophic decline in human populations as a result of contact with Europeans and the diseases they carried with them. Indeed, it is this region in which researchers were first able to prove major population declines in the New World.[22]

Can we assume that the decline in human numbers in the Western Hemisphere's most populous region, the Valley of Mexico, resulted in land abandonment and therefore in reforestation and consequent reduced atmospheric carbon levels, and, as a further consequence, increased biodiversity? The evidence is overwhelming that any such assumption would be incorrect; further, we can conclude with reasonable certainty that Spanish occupation of highland Mexico meant deforestation and often desertification of regions that were previously biologically and agriculturally more productive. As in many if not most areas of fairly dense pre-Conquest

human settlement, Spanish changes in agricultural use of the landscape also meant rampant erosion of soils that make reforestation difficult to the present day. We can reasonably conclude that biodiversity declined significantly with Conquest.[23]

Why is the equation of lower human population in Central Mexico with reforestation so misleading? First, the high population density of Tenochtitlan and surrounding city states in Mexico's central basin did depend on intensive agriculture, but more than a third of production was on raised beds in lakes and marshlands with an intensity of production that likely came close to the natural biological productivity of the area farmed. Chinampa methods included management of salinity and maintenance of the marshland environment, favoring continued survival for fish, amphibians, insects, and water plants native to the region, some of which were valued as food. Waterfowl continued to visit the cultivated and uncultivated shallow lakes and marshes and were important to local diets. Intense and highly diverse upland agriculture complemented chinampa production.[24]

However, the Spanish did not understand and did not appreciate the productivity and methods of chinampa agriculture. Landowning elites coveted shallow lakes and marshland for urban development free from floods. They worked to drain the water on which highly intensive local agriculture depended, including a particularly ambitious and agriculturally disastrous effort called the "desagűe" in the seventeenth century. Colonial and national governments continued these drainage efforts.[25] Large portions of what had been species-rich marshland were transformed into urban neighborhoods or barren salt flats. As they degraded and destroyed chinampa agriculture, and as indigenous populations and European began to increase, provisioning necessarily depended more and more on land outside the lacustrine environment of the Central Valley. This land was undergoing progressive degradation from grazing animals,

especially sheep, the plow, and other production techniques poorly adapted to the highland tropics. Melville has shown conclusively how Spanish tools, animals, institutions, and markets taken together created desert conditions in previously highly productive areas, in her case study, north of the Valley of Mexico. Geographer Carl Sauer had argued similarly a half century earlier with regard to northern deserts.[26] Until Melville's work, observers had tended to incorrectly attribute the poverty of such areas to indigenous ignorance and primitive technology rather than to land use changes introduced and enforced by Spanish imperial control and its ramifications into the modern era.

Haciendas, self-sufficiency, and grazing

Through much of central Mexico, Spanish plows and livestock, to take them as the most important and emblematic of many destructive Iberian introductions, surely meant a substantial reduction in the sustainability of agriculture and in the species richness of surrounding land. The economic depression and political disarray that hit rural areas from time to time, but particularly hard in the mid-seventeenth century Mexico, may have tempered the damage. Collapsing global markets and increasing rural violence led to the creation of relatively self-sufficient rural estates, *haciendas or estancias*. While continuing to take advantage of market opportunities when possible and providing provisioning crops to local towns, cities, and mines, *hacenderos* were more intensely concerned with security than with profit. *Hacenderos* also found satisfaction in meeting the Spanish ideal of prestigious patriarchal estate owners. This led to practices such as moving cattle across the landscape seasonally and in studied response to the pressure cattle were putting on grass and soil, using techniques well-known to the Spanish--what we in the 21st century we call seasonal or rotational grazing. In the short term, this could decrease the number of cattle on the land that could be sold annually, which was permissible and even desirable when

markets were weak, but it allowed recovery of vegetation, that when well-managed, supported numerous and healthy herds over the longer run. Such grazing techniques are known to substantially increase wild biodiversity when compared to other grazing practices.[27]

Hacenderos also depended on forest resources for a variety of purposes from erosion control to harvest of materials useful in a self-sustaining operation, such as building materials, firewood, nuts, pitch, and turpentine, and all of these products could be marketed on occasion. Haciendas were socially regressive in a variety of ways, but they probably often did succeed in creating more sustainable methods towards the goal of secure food production and physical security on the estate itself. In order to support relative self-sufficiency, the hacienda required maintenance of a complex matrix of land uses and as such almost certainly did a better job of promoting wider biodiversity when compared with commercial agriculture or desperate survival strategies of those peasants who lacked control over sufficient land. At the same time, we also can surmise that while to some extent promoting biodiversity, the hacienda shifted the composition and number of species from those of previous eras. Unfortunately, no one has developed systematic evidence about which species were favored and which undermined specifically within hacienda economies.[28]

Indigenous desert systems in Mexico

Outside of the Valley of Mexico other kinds of highly productive agriculture prevailed. In Mexico's northern deserts, indigenous people relied on an integration of hunting and gathering with a number of ingenious forms of agriculture that made the most of scarce water. Such methods, still practiced by indigenous people of the Sonoran Desert, have been shown to support more biodiversity than adjacent protected parklands.[29]

New views of ancient Meso-american forests: anthropogenic biology?

Moving from mountain highlands and deserts to lowland tropical forests, the regions that typically harbor the greatest diversity of species, the history of people and other species is complex. We are only beginning to understand it. As a result of recent archeological studies made possible by remote-sensing from satellites and aerial surveys we now know that much of the Peten forest of southeast Mexico, eastern Guatemala, Belize, and eastern Honduras was and is quite different than previously thought.[30] It once had been assumed, based largely on the practices of present-day Mayan farmers, that the dense human populations of Classical Mayan and Post-Classical Mayan culture were supported primarily by swidden agriculture. This would have been based on dense forest cover cleared and burned in rotations, allowing for forest regrowth. Some argued that it was likely that it was the increasingly short period of the rotations caused by population growth that degraded soil and led to regime collapses starting around 900AD. New remote sensing techniques have allowed us to see that Mayan lowland civilization across broad areas of the Peten was supported to a significant degree by raised-bed agriculture similar in many ways to the chinampas of highland Mexico. This realization makes it clearer than before that Mayans carried out intense transformations of forested lands; swidden agriculture on shorter than desirable rotations would have led to reduced biodiversity, while raised-bed agriculture largely replacing forests as populations increased likely would have meant even more biodiversity loss, but of different composition. On the other hand, raised-bed agriculture would have made it possible to raise far more food on far less ground, opening the question of whether the Mayans maintained relatively extensive intact forests alongside raised-bed agriculture. Or perhaps whether both methods used together may have been especially effective in degrading soil and increasing species loss as populations grew.[31]

The point here is not to settle these conjectures in favor of one or another hypothesis, but rather to point out that the Peten forest has a complex environmental history bound up with rise and fall of culturally and technologically sophisticated civilizations. Different agricultural systems used by the ancient Mayans would have had varying impacts on biodiversity within what is now considered a critical area for biodiversity conservation. It cannot be assumed, as it often is, that the richness and composition of biodiversity is the result of "natural," non-anthropogenic processes alone, nor of current indigenous agricultural techniques. Did all the major landscape changes introduced by human civilizations over millennia reduce biodiversity, or is it possible that some of these changes may have increased species richness? Nor can it be assumed, as it often is, that the present widespread practice of swidden agriculture by present-day Mayan farmers means that swidden agriculture was the only or even the most important human influence on the composition of the forest as it is in the 21st century. The Peten has a history, a natural history that for at least several millennia includes human activities of large-scale landscape transformation that we are still far from understanding. Much less do we understand the complexity of biological processes as they reacted to poorly understood human activities.

An anthropogenic Amazon?

The same can be said for the largest reservoir of biodiversity in the world, the Amazon region. It has long been assumed that the greatest remaining reserve of species in the world is due to a combination of natural factors with virtually insignificant human population density. What naturalists began to catalog in the mid-nineteenth century could be taken as the natural endowment of the region that only began to significantly change with rising human populations

in the mid-twentieth century. Recent research has raised significant doubts about this assumption.[32]

The first doubts about what we call here the "natural endowment" hypothesis arose when we began to realize that the population collapse we have documented for highland Mexico and the Andes also applied to the Amazon. Early European expeditions reported large villages or even cities spread long distances along river banks, able to mount sometimes successful resistance with armies of warriors in canoes and along the banks for agonizingly long distances. Accounts of large agglomerations of indigenous people by early expeditions were discounted by most twentieth century scholars, who relied on much later descriptions of the Amazon as virtually uninhabited. But, of course, the low human density even by the seventeenth century was attributable in large part to the impact of European disease, of which scholars were unaware until the mid-twentieth century.[33]

Europeans not only introduced disease. They also sought to exploit natural resources with little thought for long-term consequences. This was most obvious with respect to the incredible natural richness of the rivers. European newcomers were able to sharply reduce some species in relatively little time, species that had co-existed with and sustained indigenous populations for thousands of years. One of the best known of such species are the *arapaima* fish, called piraruçu in Portuguese and *paiche* in Spanish. One of the largest freshwater fish at 2 to 3 meters in length and up to 100kgs., it was a major food source for indigenous people, one they husbanded with taboos on destructive harvest methods. Similarly, river turtles were such an obvious source of valuable meat that they were farmed in large enclosures and protected by rules regarding wild harvest. Europeans did not respect indigenous rules and methods and quickly decimated the richest and most easily available food sources in the region. The *arapaima* declined so

disastrously that they were thought to be extinct by the end of the 19th century, the decline having occurred over a few centuries in which human population of the Amazon was extremely low. (In the last decades, fishing management has achieved significant population recovery in some regions, and the *arapaima* is now farmed and shipped to markets in the United States.) Turtle populations also suffered dramatic decline. The overall impact of these declines on biodiversity is hard to estimate, but it was surely significant. It appears that as the result of European disease, enslavement, and radical impoverishment of food sources, many of the peoples of the Amazon felt forced to move away from the food-rich riverbanks into more difficult interior locations outside of European reach. When encountered by twentieth century incursions into the Amazon forests and by the anthropologists who followed in their wake, these peoples were observed to be dependent on survival strategies that were very delicately balanced on the edge of failure and were simultaneously engaged in sometimes ferocious battles over territory with European settlers and other indigenous groups. [34]

At the same time, many indigenous groups had developed ingenious techniques for surviving in difficult environments. One of the most interesting and perhaps significant of these is the discovery of what non-indigenous settlers called *terra preta do indio*—"black soil of the Indian"-- that is carbon and other nutrient-rich soils that have been shown to be created by indigenous techniques to combat the infamous lack of nutrients in some Amazon soils. While such soils account for only a small percentage of the vast Amazon region, they were likely a vital anthropogenic resource. At a very plausible five percent of Amazon soil, roughly half the area of France, *terra preta do indio* could have provided sustenance to many millions of people. In any case, it is clear that people have been shaping the biological character and composition of the Amazon forest over a long period and in significant ways.[35]

As we begin to understand the history of the Amazon region over the last five centuries since European incursion, we are also finding that the human history of the Amazon goes back much further than previously thought. Instead of three millennia or so of human presence in the Amazon, new discoveries are pushing the human history of the region back as much as *thirteen* millennia or more.[36] Archeological finds are also supporting historical analysis that argue that the human population of the Amazon prior to European contact may have been as high as fifteen million, roughly equal to the population in the year 2000. In accepting such a number as possible or likely, it must be kept in mind that the Amazon Basin covers an area larger than the 48 states of the continental United States. At fifteen million, population density would still have been very low. But multiplying the human population estimates by an order of magnitude and greatly lengthening the time of human habitation implies a significantly greater and perhaps qualitatively different role for humans in shaping the biology of the forest than previous estimates suggested. We also have to account for the changes in biodiversity that may have been occasioned by the exploitation of the Amazon in such events as the rubber boom at the turn of the twentieth century. We still know relatively little about the enormous array of habitats and species in the Amazon in spite of a great deal of scientific effort. Even less do we understand the human role in shaping the Amazonian ecosystem as it is today.[37]

The biology of national independence: change or a lot more of the same?

The continuing influence of international markets

Up to now, we have mainly raised questions about what shaped the landscapes of Latin American as a result of European colonialism. Political independence gained in the first half of

the nineteenth century, however, led in a few decades to landscapes ever more chained to distant markets and distant arbiters who controlled the future of Latin American populations, human, plant, and animal. In particular, the rise of mass consumer markets in Europe and the United States created explosive demand for tropical luxury products such as coffee, chocolate, and bananas whose production displaced large areas of humid tropical forests. Railroads, steamships, and refrigeration made it relatively easy to ship Latin American agricultural products to Europe and North America.[38] The limits to the productive capacity of European agriculture also created vast demand for basic grains and meat, demand that would be met partly by the Argentine Pampas.

The prairies of the Argentine Pampas were immensely rich in biodiversity, as were the similar temperate prairies of the North American Great Plains, and remained so until the mid-19th century. With the arrival of railroads for grain transport and refrigerated ocean-going vessels, the Pampas were quickly transformed into one of the major agricultural regions of the world. Again, production was not limited by the small local populations. Argentine production was driven mostly by the dynamics of international markets, as it is today. Technological developments were similar to and occasionally led those in northern temperate prairie regions. The familiar array of a relatively small number of crops and animals and heavy dependence on agrotoxins had and have effects similar to those in North America. Biodiversity suffers accordingly.[39]

By the mid-to-late nineteenth century, most regimes in Latin America were committed to encouraging foreign investment and large-scale commercial enterprises, most notably in mining and agriculture. Land laws passed by liberal regimes undermined peasant landholding and facilitated the assemblage of large entrepreneurial ventures in agriculture. Governments offered hefty incentives for railroad building, port construction, and processing facilities to attract

investment into export agricultural activities and mining that were thought capable of providing the income and tax revenues towards general national prosperity. The new investments often came at the expense of peasant communities and communally controlled forests and water resources, as the investments were aimed specifically at unlocking land and resources for rapid exploitation. North American and especially British investors controlled the nature and pace of development to a large extent. Historians speak of a British "informal empire" in Latin America during the last decades of the nineteenth century through World War I, when the United States begun to rule the roost. Such strategies of national development continued to prevail in most of Latin America throughout the twentieth century and to the present in spite of occasional nationalist rebellions and revolutions that sought to husband national resources more carefully and use them for more general benefit.[40]

Smallholders and domestic markets

The continued expansion of agriculture has been fueled partly by the very rapid growth of domestic populations through the twentieth century. However, domestic production tended to rely more heavily on smallholder agriculture that, compared with large-scale enterprise, was more diverse and less capable of rapid advance into new territory.[41] The novel forms of landholding adopted by the Mexican government in the wake of the 1910-1920 Revolution eventually established smallholder control over something like half of national arable land. Most was in already-established agricultural zones, but some involved expansion into forested land and deserts with corresponding losses in biodiversity. However, the *ejidos* and *communes* of Mexican land reform also frequently became jealous protectors of forest land allotted to them, engaging in decades-long and sometimes violent struggles with private timber firms and agribusinesses.[42] In some cases, as in biologically diverse southern Brazil, smallholder

immigration was promoted by national governments, especially in the late nineteenth and early twentieth century, with timber sales regarded as a resource that could finance further agricultural expansion and deforestation .[43]

The great threats to biodiversity came mostly from large scale operators focused on export, or, increasingly, as in the case of Brazil, large national urban markets combined with export. They could influence governments to build transportation facilities, provide police and military protection, and furnish direct "development" subsidies. Examples include the explosion in what came to be called "rainforest beef" production in the Amazon, Costa Rica, and elsewhere that devastated huge areas of forest beginning in the 1970's. Rainforest beef typically involves the wholesale clearing of forests over vast territories, with biodiversity wiped out across trajectories of tens and even hundreds of kilometers in a matter of a few years. The destruction was frequently met with resistance from indigenous communities and smallholder settlers, but usually with limited success. In the Amazon, smallholder colonization was encouraged by governments and corporations to provide the labor needed to clear the forest, promising land and security in return. After the essential clearing was done, such colonists were typically faced with direct, often violent, removal or with economic failure as cattle firms and others moved in to occupy the land. National governments were willing to turn a blind eye to legal manipulations or violent repression exercised by private interests, or even rushed to provide official military and police support to what were formally or informally considered projects of national development. In some cases, as soils deteriorated and productivity undermined the value of such enterprises, smallholder agriculture was able to follow in the wake while bigger operators moved on to more lucrative virgin territory. As a result of all these processes, smallholders often end up being blamed for forest and biodiversity loss that they did not initiate.[44]

The new hydraulic biology of agricultural systems: dams and irrigation

Promises and disappointments

Over the last century, large-scale irrigation schemes have proliferated apace in Latin America. These schemes were usually justified by the need to provide food for domestic populations, and often on land that was already being grazed or farmed. They often were linked to land distribution schemes that were promised to enrich smallholders and provide secure and sustainable livelihoods. Irrigation schemes, whether based on dams or financing of pumps and wells, were favored by national governments, development agencies, The World Bank, and the Inter-American Bank for Development. High-yield crop varieties developed in "Green Revolution" research were usually particularly dependent on secure delivery of abundant water—dams, the high-yielding varieties, and synthetic pesticides and fertilizers were promoted as "the package" needed to make the new varieties succeed.

Not only do irrigation schemes promise food security and increased economic development to the public, but they also offer a rich bounty of construction contracts and profits in land speculation and myriad shady deals. This is especially true when irrigation projects are tied to hydroelectric dams, as they often are. However, the corruption of such schemes took many forms through fraudulent distribution of land and water to larger operators, through longer-term transfers of land and water rights out of the hands of poorly-financed smallholders, and through the diversion of water and irrigation facilities to large-scale export operations.[45]

Capital investments that were promised to make domestic food supplies cheaper and more secure were often diverted to serve more profitable markets in richer countries and/or wealthy segments of national urban populations. Formerly biodiverse forests, scrub forests, or prairie land often became biologically impoverished by salinization, perched soils, and soil

compaction. Development experts and their entrepreneurial allies could point to rising national export earnings while ignoring the long-term human and environmental price.

Irrigation and export

Frequently, irrigation schemes became one of the various means by which high-value fruits and vegetables were grown for export to Europe and the United States. For example, the very large vegetable export sector in Mexico was carved out of lowland semi-tropical and tropical dry forests teeming with species in Sinaloa and Michoacán. The production technology used usually involved lavish use of agrotoxins and other techniques that were highly damaging to local biodiversity, farmworkers, and rural residents.[46] A recent and telling example of such "development" projects in Mexico is the rapid expansion of avocado farms into pine forests that harbor critically threatened migrating monarch butterflies, with the export of the avocados controlled to a large extent by criminal organizations arising from the drug trade.[47]

Irrigation and the Brazilian cerrado

While environmentalists around the world have focused on the biological losses of Amazon development, many Brazilian observers believe that the irrigation-dependent agricultural development of the Brazilian *cerrado*, a vast and highly biodiverse semi-arid region in the Northeast and West of Brazil has been equally as tragic in terms of diversity loss. The Brazilian government from colonial days to the present has tended to see the *cerrado* as a region of endemic poverty and social problems. Beginning in the last four decades of the twentieth century, the government, in partnership with national and international development banks, large-scale agribusiness operations, and corporations has financed irrigation development of the *cerrado* through dams and deep-water wells. The result has been an ongoing agricultural boom based on soy and maize with a very high price in terms of biodiversity, perhaps a higher price

than in the Amazon. At the same time, the government has done relatively little to create the very large indigenous reserves, parks, and other protected areas of the sort it has created in the Amazon, at least partly because there has been little public support for conservation of the region due to its historically bad reputation. In the *cerrado*, as with much of Latin American agricultural development--and we may say, global agricultural development--a great deal of precious biodiversity loss has come at an exaggerated cost because otherwise environmentally concerned urban people really know so little about agriculture and so little about the land itself.[48]

The Asian connection: food and fuel

Agriculture in the *cerrado* and the Amazon depend to a considerable and growing extent on the rapidly expanding markets for soy and maize in East Asia and beef in Asia and Europe. Agriculture based on *cerrado* and Amazonian land has become a major element in the entire Brazilian economy, which has been shown in recent years to be highly dependent on events in China, just as were the colonial economies based on silver mines in the Andes and Mexico.[49] The revival and even expansion of monocrop sugar plantations to produce ethanol for the Brazilian and foreign markets has at the same time tied the fate of the land to the global carbon fuel economy.[50] Based on the ethanol boom, some mangrove swamps in Brazil's Northeast have been transformed into sugar plantations, at the expense of manatees and range of other important species.[51] All of this reminds us that agriculture and the diversity of nature in Latin America for five centuries have been strongly linked to the world as a whole.

The Amazing persistence of biodiversity in the face of loss: why?

The diverse, the vast, and the remote

This survey has emphasized the losses in biodiversity due to the kinds of agricultural development favored by colonial and national governments. After so much damage has been done, we have to ask ourselves why it is that Latin America remains the most biodiverse region on earth. The reasons are complicated, but some major factors are easily identified. First, the region is very large and very diverse in climate and terrain. Much of the most biodiverse regions of tropical forests and alpine environments remain difficult to access. National governments, led notably by Costa Rica, have become seriously committed to retaining some minimal percent of tropical forests in relatively protected status.[52] Under both military and civilian governments, Brazil has established huge protected areas of various sorts. Even in the Amazon, for a variety of reasons, wholesale forest destruction accounts for only about twenty percent of the vast regional biome.[53] Deserts and semi-arid regions often are not suitable to, or have yet to be claimed, for economic development and have not been brought under irrigation.

Cropping systems of export crops that are friendly to biodiversity

When looking at Latin American agriculture, it is also happily the case that some of it remains to one degree or another friendly to biodiversity. Coffee and cocoa are grown in what were in the mid-nineteenth century vast humid tropical forests. While most coffee farmers rely on severe monocropping techniques that seek to eliminate all competitors to the coffee plant and maximize sunlight captured by the plants, some coffee planter use far more sophisticated methods. Using such methods, coffee plants grow among native trees and vegetation, providing habitat for insects that provide control of some major coffee pests. Shade improves the quality of the crop. Productivity is high enough to ensure profitability, and with greater security. Studies have shown that coffee grown in this way can support diverse plant and animal species. Insect

biodiversity, a particularly good indicator of forest health, may be as high as 85% as that of surrounding uncut forests. [54]

Shade-grown coffee has benefited from traditional practices and the carefully developed knowledge of entrepreneurial farmers. Careful and knowledgeable management is essential. High management requirements can favor smallholder production capable of maximizing the value of the grower's expertise while minimizing the high capital expenditure required on sun coffee farms that rely heavily on agrotoxins. Recent agronomic research has strengthened the ability to ensure control of scale and other pests and diseases. Such systems have achieved success in southern Mexico, Central America, Colombia, and Brazil. Shade-grown coffee can be grown as a single export cash crop, or it also can also be one excellent element on a diverse farm that cultivates subsistence and local market crops.

Cocoa can benefit from similar treatment. Shade-grown cocoa farms have been used for a long time by smallholders in Africa and Meso-America, but in Brazil they developed on large holdings. Cocoa planters often maximized the size of their holdings and sought to minimize the management attention they exercised. While many planters cut all competing vegetation and controlled its resurgence as much as possible, some planters cut a minimum of existing vegetation consistent with the survival of young cocoa trees and/or allowed the vegetation of the surrounding forest to regrow along with the cocoa trees. Arguments among planters and agronomists have continued over more than a century regarding the relative profitability of shade and sun-grown cocoa, but many planters have continued to favor the shade-grown methods for all that time. Though such cropping methods have often grown out of benign neglect, it is increasingly clear that they can be enriched by agronomic and ecological expertise. As in similar coffee plantations, researchers have shown very high biodiversity within shade-grown systems.

As with coffee, planters now seek out certification from international organizations that are willing to provide contracts that guarantee higher and/or more secure prices for some combination of "organic," "shade-grown," "bird friendly," and "fair trade" labeling.[55]

Protected areas and "cooperative management"

There are vast areas in Latin America devoted to grazing or highly dispersed farming with remarkable biodiversity. One of the most important of these is the Pantanal of Brazil, Bolivia, and Paraguay--a marshy, seasonally flooded landscape that harbors a spectacular array of aquatic and terrestrial species. It covers an area as large as France. For nearly two centuries it has been used by ranchers to raise beef cattle on large landholdings, but a diverse range of native species has survived and even thrived. When conservation organizations began to appreciate the biological abundance of the Pantanal, local and national politics compelled them to enter into negotiations with local landowners who argued that experience had already proven that their methods were consistent with the survival of wildlife. Negotiated management plans proved mostly successful in meeting the goals of ranchers and conservationists while improving ranch incomes through the development of ecotourism.[56]

For reasons that are not well understood, some economically valuable aquatic species have suffered sharp declines recently. In 2020, enormous, uncontrollable fires swept across the Pantanal. Fires are a danger, but they almost certainly have been present for millennia in the Pantanal and in some ways enrich biodiversity and increase the profitability of ranches. Some degree of species loss is a feature of all dynamic ecosystems and especially when novel kinds of human presence enter the picture. The Pantanal will continue to be of concern as one of the most biodiverse regions of the planet, and the threats to its integrity will not disappear. However, compared to the wholesale destruction that has characterized many other regions, the Pantanal

demonstrates forcefully that significant human economic activity can be consistent with high levels of species diversity.

Negotiation between governments, ranchers, resource extraction companies, and foreign "eco-philanthropists" has also resulted in a long-evolving conservation program at the far end of the South American continent in Patagonia. The species-rich area of Chile and Argentina includes alpine environments, lowland plains, unique temperate rainforests, and species-rich coastal areas. Some 14 million acres have become in some sense "protected." While parts have been heavily abused by logging and ranching, other parts are still biologically rich although they have long been grazed or farmed and continue to be. In this area, there are now thirteen national parks, two marine parks, and large expanses under some kind of "conservation management" that includes ongoing economic activity. Particularly because of the important role of Doug Tompkins, an "eco-philanthropist" from the United States, and because of the designation of part of the conservation areas as "private protected areas" (PPA), the plans have come under intense scrutiny and will remain a controversial experiment for some time.[57]

Biodiversity-friendly practices of contemporary smallholders

Throughout Latin America, traditional farmers have often created agricultural landscapes that are friendly to biodiversity. Traditional farmers—whether indigenous or not--tend to rely on a diversity of crops and even of diverse varieties of the same crop to insure food and income security. For example, Andean potato farmers commonly plant diverse potato varieties across the same field to maximize the use of known fertility and moisture conditions in each part of the field that are best adapted to particular varieties. They even plant certain varieties in a portion of the field simply because variety is valued for its own sake—similar to the widespread practice in Mexico and Central Mexican of maximizing the variety of kernels of different colors even when

no precise rationale is known—though the science of genetics suggests clear advantages.[58] It is common practice in semi-arid regions of Mexico, and elsewhere, to retain trees within or along field boundaries because they are thought to assist in maintaining soil moisture. Trees and forests are valued for providing mulch or compost materials, for harboring insects or birds that control crop pests, or for controlling erosion. Fields are frequently left fallow if farmers control sufficient land to afford to do so. Traditional farmers often cannot afford or deliberately avoid lavish use of agrotoxins, and in any case can not apply them all at the same time across vast expanses, as is common in large-scale industrial agriculture.

Traditional farmers, when not driven too hard by land scarcity, will usually prefer to scatter holdings and fields across a landscape, leaving patches of brush and forest. Some agricultural experts complain about the messy look of traditional farms and the "waste" of land not all of which is pushed to maximize crop yield. Others recognize that in important and productive ways this seeming messiness on the landscape mimics to a degree the form and structure of natural ecosystems that provide stability to farming systems as they do for wild biodiversity. In some cases, such practices are part of highly sophisticated farming systems that may have come from millennia of the development of traditional knowledge. In others, they may have been adopted recently on the advice of agronomists working for the government or for social movements.[59]

Many families who farm smallholdings but are not traditional inhabitants of their region practice agriculture that is relatively friendly to biodiversity when compared to large monocrop fields of industrial agriculture. They may do so because they have adapted prevailing practices of traditional farmers when they moved into the area, enjoying the same rewards to diversity as

traditional farmers. There are a series of other reasons as well. Crop variety offers security against unpredictable weather conditions. Many plant pests and diseases are very crop-specific and crop variety provides insurance for this reason, too. Flexibility in crops planted also allows adaptation to the fluctuations in crop prices and in availability and price of agricultural inputs.[60]

When farmers rely heavily on producing commodities that are mostly grown by large operators and sold in national and international markets, they are subject to the large and sometimes extreme price swings characteristic of such commodity markets. Large firms have a variety of ways of surviving price instability, but smallholders typically do not. Local and regional markets for a wide variety of foodstuffs, in contrast, offer greater price stability. Smallholders have direct knowledge of more local markets, while larger operations have better knowledge of national and international markets. Bulk commodity producers indulge in deliberate manipulation of such markets when they have sufficient market share or financial partnerships with trading companies who are the most powerful actors regarding commodities. Growing a variety of local market crops can provide insurance against market fluctuations to smallholders who will never be in a position to reliably prosper when predominantly producing for large and distant markets.[61]

In most of Latin America, while large operations dominate export commodity production, smallholders provide a very large portion of national food needs, in most countries well upward of half. In Brazil, characterized by large landholdings for export agriculture, but also characterized by relatively vigorous government support programs for family farms, smallholders produce about 38% of agricultural exports but around 70% of the food consumed in Brazil. Accordingly, relatively small family farms and traditional farms are a large part of the

agricultural landscape, although the proportion of land they occupy is usually small compared to proportion of food they produce for regional and national markets rather than international ones.[62]

The landscape matrix

It would not be accurate to say that smallholder agriculture guarantees higher biodiversity than larger operations. But that is the tendency. An alert airline passenger can readily perceive some of the reasons. Seeing single fields of thousands of hectares devoted to soy or maize, as one does when flying over some deforested areas on the southeastern edge of the Amazon and in the neighboring *cerrado,* and then seeing the much more complex landscapes of smallholdings in Minas Gerais and Sao Paulo, one readily appreciates such differences. There is a kind of terrible beauty to the uniformity of the large monocrop expanses seen from thirty thousand feet, but it is obvious that from the point of view of a wild plant or animal, the complex smallholder landscapes present far more places to make a home and a living—boundary hedges of brush and trees, forested creek bottoms, patches of forest left here and there, a variety of crops of different colors, heights, and density--crops that will offer a poaching animal different kinds of nutrients, maturing at different times of the year.

Brazilian forest law has recognized the importance of maintaining forests as agriculture claims greater shares of the landscape. It has required that farmers leave given percentages of land—ranging from 20% to 80%-on a given landholding in its undisturbed state. The law particularly aims to protect the vegetation and integrity of creeks and river corridors. Unfortunately, the law has been widely violated, and the administration of Jair Bolsonaro elected in 2018 has sought to weaken it. The administration has made it clear that it does not intend to

rigorously enforce such laws, putting the emphasis on rapid growth of agricultural production and rapid expansion into the Amazon and the *cerrado*.[63]

Fortunately, we do not have to rely on our immediate impression to know that from the point of view of biodiversity, the small, diverse field environments offer a biologically much richer landscape. Researchers have verified that this is the case. They also have verified that the fragmentation of forest environments as in Minas Gerais, Sao Paulo, and in much of the Amazon can lead to species loss much greater than the sum of the area deforested. To protect biodiversity, we need specific landscape elements: in general, smaller rather than larger field size; larger rather than smaller strips of continuous forested areas; corridors of undisturbed creek bottoms or rivers; landscapes and waterways relatively unpolluted by industrial or agricultural toxins; and a variety of other landscape characteristics that vary from region to region. If we think of landscapes outside of the barren uniformity of commodity production under industrial agriculture, we see a matrix of landscape uses and characteristics and we can investigate what type of matrix most favors biodiversity and what type does not. We can do research about what types of biodiversity are most favored by what kinds of matrix or matrices.[64]

Crop diversity and farming in the physical space of complex landscapes and high biodiversity is demanding in the sense that it requires a great deal of knowledge and ability to make good decisions in response to changing conditions. Knowledge is key. It may come from a variety of sources, including the passage of knowledge through generations that the term "traditional" farming evokes. However, traditional knowledge is often lost as social, economic, and technological change makes it less relevant and/or more difficult to pass on.

Social movements and agroecology

There are various ways other than tradition that the required knowledge can be generated and brought into practice. Social movements have played a key role. The environmental movement has raised consciousness about the practical as well as the intrinsic value of biodiversity, and, in turn has influenced agricultural scientists and technicians to think about how agriculture "can be married to ecology." Land reform movements and associations of small and family farmers have sought the knowledge necessary for survival of small-scale agriculture. They have increasingly appreciated the importance of preserving crop and wild biodiversity. Many agricultural scientists in universities and research institutions around the world have become disillusioned with seeing the way their research has been increasingly enlisted in the service of a steadily more industrialized agriculture that displaces family farms and wreaks environmental havoc, and they have explicitly or implicitly allied themselves with small farm and environmental movements.[65]

In Latin America in particular, these movements and their visions have come to travel more and more under the label of "agroecology." There are now university undergraduate and graduate programs in agroecology, a professional association, and periodic conferences held throughout the region. The Brazilian Movement of Landless Rural Workers (Movimento dos Trabalhadores Rurais Sem Terra or MST), an organization for land reform in Brazil, has adopted agroecology approaches as its official national policy in 2001 and has done much to develop, teach, and disseminate agroecology practices. Via Campesina, an international organization of peasant movements also promotes agroecology approaches. The agroecology movement has become widely influential throughout Latin America and clearly even has a modest influence on agricultural scientists and practitioners working in industrial agriculture.[66]

Protected and inhabited: trends in conservation management

The idea of a smallholder agriculture that is closely allied with environmental ideas and social movements is given additional impetus by major trends in the creation and operation of protected areas in Latin America. There are few habitable landscapes in Latin America that are not currently *inhabited landscapes*. There are a variety of national parks and other protected areas throughout Latin America that are primarily focused on preserving particular spectacular or highly valued natural sites and locations and that exclude agriculture and other economic activity other than recreation, as is common in the United States and Europe. However, conservation protection in Latin America has in recent decades focused more commonly on extending legal protections and designations to areas in which agriculture is practiced. These include large indigenous reserves, often in tropical forests. They also include extractive reserves, in which local people may legally practice such activities as rubber gathering and sustainable timber harvest combined with fishing, hunting and small-scale agriculture. Many biosphere reserves explicitly devoted to biodiversity preservation also allow for some kinds of agriculture by people resident in them. What is notable is that there are so many and such large areas in Latin America that are inhabited and that conservationists believe deserve attention as areas rich in biodiversity. While the recognition of a degree of compatibility between conservation and livelihoods is a legitimate cause for celebration, it would be foolish to think that all is well, or even getting better. The crisis of species loss continues.

Biodiversity and five centuries of exclusion: is cooperation really possible?

It is also essential to see that the history of agriculture in Latin America as related here has consistently meant the investment of most public and private capital in large-scale operations conceived in the context of the international economy rather than domestic food security. With a few exceptions, most have been ruinous in terms of biodiversity. Another result has been to

exclude peasants, smallholders, and indigenous people from economic prosperity. If they live largely outside of the market, they have been undermined and often attacked in ways that make traditional healthy communities and traditional livelihoods impossible. Where they participate actively in markets, they are often squeezed out of land, investment, and opportunity by larger operations that are able to seize advantages of many kinds. It is many of the rural poor who, by the nature of their livelihoods and their locations, have nonetheless deliberately or inadvertently protected biodiversity. Or, another way of seeing it is that a large share of plants and animals and the majority of the rural population have shared the fate of being pushed out of the most agriculturally productive lands. The poor and a great range of species seek to survive in what in economic terms are marginal landscapes but in conservation terms have great value.

A critical set of issues, too complex to treat here, surround the attempt to manage such areas in ways that are mutually satisfactory to the people who live in them and to those in government or conservation organizations who have some management authority related to the conservation of species. Conservationists frequently are disappointed at the performance of rural people as conservation agents and the rural poor frequently feel betrayed by what they see as yet another imposition of unrealistic demands on their very limited ability to thrive in difficult circumstances—yet another injustice. A recent literature review revealed that a key problem is the failure of conservationists to recognize that, "Far too often, words such as 'collaboration' and 'consultation' in conservation practice have become shams for the maintenance of pre-existing social structures." If it is not recognized that the conservation landscape is also to a large extent a landscape arising out of five centuries of social exclusion, the realities of the challenges cannot be properly identified, much less overcome.[67]

Discussion of the Literature

For the sake of sharpening the discussion, and for brevity, this article has drawn primarily on the literature in the relatively new field of environmental history. There are many other discipline-based literatures that would add essential elements to the discussion. For this topic, among some of the richest of these fields and sub-fields are ecology, geography, historical geography, agricultural geography, environmental studies, conservation biology, ethnobotany, economic botany, agricultural history, agroecology, economic history, social history, anthropology, ethnography, development studies, and rural sociology. Each of these fields makes its own contributions and develops its own framework for discussing the issues.

Although scholars often have difficulty in dealing with literary sources, the fact remains that some of the richest accounts of landscapes and their plant and animal inhabitants come from novels and poems. Virtually every country of Latin America has a literature of "regionalism" based on the cultural significance of diverse landscapes. There is a great deal of what anthropologists call "thick description" in this literature that is applicable to thinking about the topic of biodiversity and agriculture, and also to thinking about what people have been thinking about these matters. A large portion of this literature contains powerful and sometimes detailed lamentations regarding the loss of plant and animal variety due to human activity. In most of Latin America, "regionalism" as a literary trend was most popular in the 1930's through the 1950's, although many relevant works have been written before and after these years. Two of the most powerful and influential examples (in English translation) are, Euclides da Cunha, *Rebellion in the Backlands*, (translated by Samuel Putnam, Chicago: Phoenix Books, 1944) a peculiar kind of non-fiction literary or journalistic account of a historical event, and João Guimaraes Rosa, *The Devil to Pay in the Backlands,* a novel (translated by James L. Taylor and

Harriet de Onís, New York: Knopf, 1971.) Interestingly, the word "backlands" occurs in neither of the original language titles, and the books document quite distinct "backlands" landscapes of the Brazilian interior, which are misleadingly thought of by many Brazilians and foreigners alike as being the same kind of place. Da Cunha was trained as a military engineer and Guimaraes Rosa as a medical doctor, which at least partly accounts for the precision of their descriptions of natural history. The intellectual milieu that has produced the scholarly historical literature in Latin America always thrown scholars, practitioners, and literary authors together, with history and literature enriching each other in reciprocal fashion

In the more strictly historical literature, before the advent of explicitly environmental history, the fields of social and economic history often covered environmental themes. Such historical accounts often pictured the landscape as a template upon which human events were laid down. They also often counted the costs of environmental degradation, such as deforestation and soil erosion, in terms of explaining endemic poverty and in terms of limiting future economic possibilities. Some of this literature drew on the strong intellectual influence of Marxism in Latin America, leading to an interest in seeing history in material terms. It is now fashionable to relate much of this kind of history to the *Annales* school of historical thought as in the works of Fernand Braudel on the Mediterranean, but much of it was written before Braudel, and much was written later in ignorance or disregard of the *Annales* approach. More recently, there has been a strong interest in "frontier studies" that carries on many of the preoccupations of older social and economic history.

Primary Sources

The size of this topic implies an enormous range of primary sources, but it also necessarily limits the discussion to covering only a few of the myriad possibilities. The

beginning point is to think about who would be making observations about landscapes, natural history, and agriculture and what kinds of literature and documents they produced.

Latin American historians have for nearly two centuries relied on what relatively few indigenous documents survived conquest, though they are still deriving new lessons from them. They have also mined the reports of explorers, priests, royal officials, estate managers, and travelers. In Spanish jurisdictions with settled indigenous populations, records of lawsuits providing documentation of disputed landownership are common and sometimes provide descriptions of forests or fields. Portuguese land law, with its emphasis on the "effective use" principle has left us with documentary evidence of deforestation because cutting down existing forests was frequently offered as evidence of having put the land to economic use. This principle continued to apply until the late 20th century, leaving a trail of documented forest destruction.

In general, documents applying to land titling, land sale, and inheritance are useful in building a picture of landscape change. Land title applications, sales documents, loan documents, wills, and legal inventories often require surveys, maps, and descriptions of not only the boundaries but also the kinds of vegetation—forest, harvested forest, field crops, orchards, and pasture—that are present. There are biases and fraud in such documents, but it is usually possible to at least roughly account for these problems. Throughout Latin America, state and municipal archives safeguard such documents because of their continuing legal value.

Plantation and estate records are not saved as systematically, but many survive and some have great value in documenting what is happening on the land. Traveler accounts often provide at least somewhat disinterested if often poorly informed records of landscapes, flora, fauna, and agricultural activity. Records of Jesuit and other religious missions have proved a rich resource that is relatively easy to locate and access.

In many regions, the best use of land was a matter of prolonged and often heated debate. These debates can be found in regional newspapers, agricultural journals, pamphlets, and books that are often collected in local, state, or national libraries and archives. These are by nature polemical documents, and careful interpretation is essential in coming to any conclusions. The appearance of foreign investors on local scenes frequently heated up such debates, so the historian will often find rich sources leading up to and continuing through the establishment of banana, coffee, cacao, henequen, cotton, tobacco and other export plantations. Merchants diaries, journals, and accounts are sometimes available to further understand such conflicts. The archives of large international commodity producing and trading firms can be rich sources, such as those of the United Fruit Company, for example.

International, national, regional, local, and university research institutions have created a massive literature on land, resources, and agricultural activity in Latin America over the last century and a half. Much of this literature is now available not only in archives but in article and book form. At least some of this printed material in historical retrospective can be considered primary material rather than secondary material in the sense that it can be seen now from a much different perspective than the one of those who produced it. The archives of such institutions as the Rockefeller Foundation, so important to Latin American and global agricultural research, are available to researchers, with much material online.

Beginning as early as the mid-eighteenth century, local scholars influenced by the European enlightenment began to catalog local flora and fauna in the spirit of and contributing to the efforts of European encyclopedists. A century later, North American and European botanists and zoologists continued to provide surveys of Latin American biological resources in ways that served the purposes of empire building, as documented by various historians, such as Stuart

McCook, in *State of Nature: Science, Agriculture, and Environment in the Spanish Caribbean, 1760-1940* (Austin: University of Texas Press), 2002. The scientists involved left well-informed and well-organized paper trails accessible through various archives.

The Portuguese royal authorities, and after, Brazilian imperial officials invited scientists and artists to document and catalog the immense territory over which they ruled and about which they knew very little. Most of this material is available in various archives and museums as well as in beautifully produced printed volumes. When Maximillian invaded Mexico, he carried out a similar though less-thorough effort to survey the nature of the Mexico he sought to rule, leaving rich sources of biological and agricultural knowledge. The positivist officials of Porfirio Diaz's regime were similarly concerned with careful documentation of the natural resources of Mexico, producing valuable studies over decades.

Museums, botanical gardens, and other scientific institutions have collected, in addition to physical materials and specimens, written materials such as diaries, research notebooks, catalogs of materials, and narratives from scientists in recent centuries. These usually are available to the public, often online. Excellent examples are Kew Gardens, the Harvard Ethnobotanical Museum, the Field Museum of Chicago, the Office of Tropical Studies, and the Smithsonian. Most nations of Latin America have one or more similar institutions. One excellent example is the Botanical Garden of Rio de Janeiro, established at the beginning of the 19th century, when the Portuguese monarchy was transferred to Brazil to escape Napoleon's armies. The Bancroft Library in Berkeley, California, the Huntington Library in Pasadena, California, and various collections of the University of California at Los Angeles are other excellent examples. Throughout Latin America, state, provincial, and national Institutes of Geography and History have been collecting an amazing variety of materials, usually since the mid-to-late 19th

century. Because of lack of resources, their holdings are not always well-cataloged, but there is a great deal of little-known and valuable material in such institutions.

Much of the history of biological change in Latin America can be seen through the development of "projects" that deliberately modified the physical and biological environment and were implemented or supported by colonial and national governments. The drainage of Mexico City referred to in the main text here is an example going back to the early 16th century. The result is that rich documentation for many kinds of landscape and biological change exists in colonial and national archives. For the last several decades, private corporations, governments, and multilateral development banks such as the World Bank and the InterAmerican Development Bank have been required to prepare extensive documentation, called "environmental impact statements" or something similar, for thousands of planned projects and policies. Among such projects are "protected areas" of various kinds, with proposals for such areas usually offering exceptionally rich materials on the biological resources of the area and real or potential changes in them. While there is an obvious bias toward developmentalist purposes, much of the material, for better and worse, seems to be produced with the belief that no one will care nor pay attention, so biologists are often left to do competent work without a great deal of scrutiny from their superiors. Many such projects have been subjected to further scrutiny by official and non-official panels of experts, "stakeholder groups," non-profit environmental groups, and independent scholars. These documents tend to be readily available and are often accessible online.

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Stanley Stein, *Vassouras: A Coffee County, 1850-1900: The Roles of Planter and Slave in a Plantation Society* (Princeton: Princeton University Press) 1958
Richard Tucker, *Insatiable Appetite: The United States and the Ecological Destruction of the Tropical World* (Berkeley: University of California Press) 2000.
John Vandermeer, Ivette Perfecto, *Ecological Complexity and Agroecology* (New York: Praeger) 2018.
Christopher Wooley, "The Forests Cannot be Commons": Spanish Law, Environmental Change, and New Spain's Council on Forests." *The Americas, V.77, 1, jan. 2020, 41-71.*

Angus Wright, *The Death of Ramon Gonzalez: The Modern Agricultural Dilemma* (Austin: University of Texas Press) 2nd ed. 2005.
Andrea Wulf, *The Invention of Nature: Alexander Humboldt's New World* (New York: Vintage) 2019.
Karl Zimmerer, *Changing Fortunes: Biodiversity and Peasant Livelihood in the Peruvian Andes* (Berkeley: University of California Press) 1997.

Further Reading

There is a wealth of material that illuminates this topic, but a dearth of sources that take on the topic as a whole, or even substantial pieces of it. The word biodiversity has not been in common usage until recently, and, in the past, concern with the natural world and species was usually put in different terms and did not tend to focus on overall species numbers. It has perhaps been the prospect of a generalized and precipitous decline in species that has brought the word "biodiversity" to the fore.

Alexander von Humboldt was the unparalleled pioneer in bringing an intense interest in natural abundance and variety to the center of scientific and popular attention in the early 19th century, and his Latin American travels influenced him strongly. He also made shrewd observations about the agriculture he observed. Andrea Wulf's very readable tribute to him, *The Invention of Nature: Alexander von Humboldt's New World (New York: Vintage, 2019)* has aroused controversies of various sorts, but whatever Wulf's errors, the book remains a good starting point for understanding the roots of ecological science as well as Humboldt's contributions. The obvious species abundance of the Amazon forest gained the attention of mid-19th century naturalists, Spruce, Bates, and Wallace, and a readable and scholarly treatment of their work again serves as a good introduction: John Hemming, *Naturalists in the Amazon:*

Wallace, Bates, and Spruce in the Amazon (London: Thames and Hudson), 2015. Among other things, it reminds us of the way that observation of Amazonian biodiversity led to the independent, simultaneous formulation of the idea of natural selection by Wallace, acknowledged as such by Charles Darwin, another scientist influenced strongly by travels in Latin America.

Only recently have there been serious attempts to systematically draw together the themes of biodiversity and agriculture. The viewpoint taken in this article is best developed in Ivette Perfecto, John Vandermeer, and Angus Wright, *Nature's Matrix: Linking Agriculture, Biodiversity, and Food Sovereignty* (London: Earthscan from Routledge, 2nd ed, 2019). This book presents recent theoretical developments and empirical studies in ecology focused on implications for biodiversity conservation, combined with field experiences and historical scholarship regarding agriculture. Geographer Karl Zimmerer has been working along similar lines with an emphasis on the Andes that helps balance the focus on Brazil and Meso-America in the present article. See, *Changing Fortunes: Biodiversity and Peasant Livelihood in the Peruvian Andes* (Berkeley: University of California Press), 1997, and the anthology, with Stef de Hahn, *Agrobiodiversity: Integrating Knowledge for a Sustainable Future, v. 24* (Cambridge: MIT Press), 2019.

Perfecto and Wright participated along with hundreds of other experts in the International Assessment of Agricultural Technology for Development, whose voluminous materials, including a large section on Latin America, are available online at (https://www.weltagrarbericht.de/reports/LAC/v.html). The IAASTD study, inspired by the Intergovernmental Panel on Climate Change (IPPC), strongly emphasized a need to turn away from the prevailing techniques of industrial agriculture in the interests of biodiversity, climate

change mitigation, environmental health, and social welfare. This message was particularly strong in the Latin American portion of the work.

In contrast to the previous studies, some scholars have sounded the alarm on biodiversity decline while urging the establishment of vast new protected areas, putting little or no emphasis on changing agricultural practices. For example, the eminent biologist, E.O. Wilson, in *Half-Earth: Our Planet's Fight for Life* (New York: Norton Liveright, 2016) argues for "protected areas" to be expanded from about fifteen percent to fifty percent of earth's land surface to protect biodiversity, while largely ignoring the implications of agricultural technologies. Wilson also has been strongly influenced by his research experiences in Latin America.

Returning to a historical focus to illuminate present controversies, Alfred Crosby analyzes an immense body of research on the exchange between the New World and the Old of plants, animals and human ideas and technologies associated with them in his two seminal books, *The Columbian Exchange: Biological and Cultural Consequences of 1492* (New York: Praeger) 30th ed, 2003, and *Ecological Imperialism: The Biological Expansion of Europe, 900-1900.* (Cambridge: Cambridge University Press) 2nd ed. 2004. Crosby's work is an excellent starting point in thinking about biodiversity in the context of five hundred years of Latin American experience.

The findings of the relatively new field of "environmental history" are summarized in the chapters of *A Living Past: Environmental Histories of Modern Latin America,* edited by John Soluri, Claudia Leal, and Jose Augusto Padua (New York: Berghahn) 2018, with a strong but not exclusive emphasis on the history of agriculture. Shawn Miller's *Environmental History of Latin America* provides a quick but somewhat older overview that contrasts with this article in some of its interpretations. There are several works that emphasize the destructive features of agricultural

development in Latin America and that have become classics in the field. Elinor Melville's, *A Plague of Sheep*: *Environmental consequences of the conquest of Mexico* (Cambridge: Cambridge University) 1994 has become essential reading. Warren Dean chronicles five centuries of destruction in Brazil's Atlantic Coast Rainforest, thought to be the most biodiverse rainforest in the world, in, *With Broadax and Firebrand: The Destruction of Brazil's Atlantic Forest* (Berkeley: University of California Press) 1995. The Cuban scholar, Reinaldo Funes Monzote, gives a similarly detailed study of rainforest destruction in Cuba in, *From Rainforest to Canefield in Cuba: An Environmental History since 1492* (Chapel Hill: University of North Carolina Press) 2008. An older classic work, *Vassouras: A Coffee County, 1850-1900: The Roles of Planter and Slave in a Plantation Society* (Princeton: Princeton University Press) 1958, by Stanley Stein, gives us a very detailed history of the destructive character of coffee agriculture in 19th century Brazil, while demonstrating that what was once called social or economic history often served well the purposes of what is now called environmental history. Tucker's *Insatiable Appetite: The United States and the Ecological Destruction of the Tropical World* (Berkeley: University of California Press) 2000, portrays largely late 19th and 20th century exploitive enterprises undertaken by United States firms in Latin America and elsewhere and is thus an overview of the kind of enterprise so widely promoted by Latin American governments from the mid to late 19th century to the present. In *The Death of Ramon Gonzalez: The Modern Agricultural Dilemma* (Austin: University of Texas Press) 2nd ed, 2005, Angus Wright places mid-twentieth century "Green Revolution" research begun under United States auspices in Mexico in the context of environmentally destructive agricultural initiatives undertaken in the name of "national development." Chris Boyer illuminates with special skill the struggles of peasants in Mexico to wield the political power necessary to advance their own livelihoods in a

deteriorating environment, and in particular, to protect forests vital to their interests, in *Political Landscapes: Forests, Conservation, and Community in Mexico* (Durham: Duke University Press) 2015.

An anthology which provides a refreshingly new approach to not only *what* we think but about *how* we think about the world's most biodiverse forests is, *The Social Lives of Forests: Past, Present, and Future of Woodland Resurgence*, (Chicago: University of Chicago Press) 2014, edited by Susanna Hecht. Cynthia Radding's work on desert cultures of northern Mexico shows how much of this way of thinking can be applied in contexts radically different from rainforests in *Wandering Peoples: Colonialism, Ethnic Spaces, and Ecological Frontiers in Northwestern Mexico, 1700-1850* (Durham: Duke University Press) 1997.

Agroecology, while applicable on all continents, developed most strongly in Latin America, at least partly in response to the processes described in this article. Two basic textbooks are available from Altieri and Gliessman, both of whom have been heavily influenced by their research and practice in Latin America. Miguel Altieri, *Agroecology: The Science of Sustainable Agriculture* (Boulder, Co: Westview) 2nd ed. 1995. Stephen R. Gliessman, *Agroecology: The Ecology of Sustainable Food Systems* (Boca Raton, Fl: CRC Press) 2014. John Vandermeer, in addition to a textbook on agroecological practice, has a more recent volume written with Ivette Perfecto, that incorporates more ecological science especially appropriate to this article, *Ecological Complexity and Agroecology* (New York: Praeger) 2018.

Notes

[1]*World Decline in Biodiversity: IPBES Global Assessment on Biodiversity and Ecosystem Services*. Bonn: IPBES Secretariat. 2019.

Biodiversity Conservation in Latin America and the Caribbean: Prioritizing Policies (Environment for Development), Allen Blackman, Rebecca Epanchin-Niell, Julia Siikamäki, Daniel Velez-Lopez. London: Routledge 2014.
Major resources include: United Nations Environment Program UNEP Knowledge Repository and Open Data Portal; Forest History Society Archives; Global Biodiversity Information Facility (see) Yesson C, Brewer PW, Sutton T, Caithness N, Pahwa JS, Burgess M, et al. (2007) How Global Is the Global Biodiversity Information Facility? PLoS ONE 2(11): e1124. https://doi.org/10.1371/journal.pone.0001124)

[2] *The State of Biodiversity in Latin America and the Caribbean: A Mid-term Review of Progress Towards the Aichi Biodiversity Targets.* UN Environmental Program. 2016.

[3]For an exhaustive critique of industrialized agriculture and suggested alternatives in Latin America, see International Assessment of Agricultural Science and Technology for Development (IAASTD) Cf. *Agriculture at a Crossroads, Latin America.* Washington D.C: Island Press. 2009. For an example of an eminent biologist arguing for maximum areas in protected status while *not* contemplating the threat of industrial agriculture, see, E. O. Wilson, *Half-Earth: Our Planet's Fight for Life.* New York: Norton Liveright, 2016. *See also,* "More than 50 countries commit to protection of 30% of earth's land and oceans." *The Guardian,* Patrick Greenfield and Fiona Harvey, Jan.11, 2021.

[4] A short and telling literature review that remains relevant in identifying key arguments and suggesting a synthesis is, Claire Kemmen, "Reframing the Land-Sparing/Land Sharing Debate in Biodiversity Conservation," *Annals of the New York Academy of Sciences 1355,no.1(October 2015).*

[5] Ivette Perfecto, John Vandermeer, Angus Wright, *Nature's Matrix: Linking Agriculture, Biodiversity Conservation, and Food Sovereignty.* London: Earthscan from Routledge, 2019

[6] A beginning historical survey with brief materials on agriculture, forests, mining, and sugar, to be treated below is, Shawn Miller, An Environmental History of Latin America. Cambridge: Cambridge U. Press. 2007, esp. ch 1-3.

[7] Alexander Koch et al. "Earth System Impacts of the European Arrival and Great Dying in the Americas after 1492." *Quaternary Science Reviews* 207 (March 2019) 13-36.

[8] Elinor G.K. Melville, *A Plague of Sheep: Environmental consequences of the conquest of Mexico*. Cambridge: Cambridge U. Press. 1994.
Angus Wright, *The Death of Ramon Gonzalez: The Modern Agricultural Dilemma.* Austin: University of Texas. 2nd ed. 2005, esp. ch5.

[9] Alfred Crosby, *The Columbian Exchange: Biological and* Cultural *Consequences of 1492.* New York: Praeger. 30th ed. 2003.
Alfred Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900-1900.* Cambridge: Cambridge U. Press. 2nd ed. 2004.

[10] There is a large literature on these and similar institutions. A good beginning is: Charles Gibson, *The Aztecs Under Spanish Rule.* Palo Alto: Stanford U. Press. 1964. For a brief summary of Portuguese colonial and national Brazilian land law, see Angus Wright and Wendy Wolford, *To Inherit the Earth: The Brazilian Landless Movement and the Struggle for a New Brazil.* Oakland, California: Food First Books, 2003. 20-25.

[11] Sidney Mintz. *Sweetness and Power: The Place of Sugar in Modern History.* New York: Penguin Books, 1986.
Warren Dean. *With Broadax and Firebrand: The Destruction of Brazil's Atlantic Forest.* Berkeley: University of California Press. 1995.

Reinaldo Funes Monzote. *From Rainforest to Cane Field in Cuba: An Environmental History since 1942.* Trans. by Alex Martin. Chapel Hill: University of North Carolina Press, 2008.

[13]Studnicki-Gizbert, Daviken and David Schecter. "The Environmental Dynamics of a Colonial Fuel Rush: Silver Mining and Deforestation in New Spain, 1522 to 1810." Environmental History 15, no.1(2010): 94-119.
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Nicholas A. Robbins. *Mercury, Mining, and Empire: The Human and Ecological Cost of Colonial Silver Mining in the Andes.* Bloomington: U. of Indiana Press. 2011.
[14] Tutino, *Making a New World*, ch.1
[15] Thomas D. Rogers. *The Deepest Wound: A Labor and Environmental History of Sugar in Northeast Brazil.* Chapel Hill: U. of North Carolina Press. 2010. See also, Dean, Funes Monzote.
[16] Van Ausdel, Shawn and Robert W. Wilcox. "Cattle Ranching and Landscape Transformation." In *A Living Past: Environmental Histories of Modern Latin America,* John Soluri, Claudia Leal, and Jose Augusto Padua. New York: Berghahn. 2018.
Jordan, Terry G. "An Iberian lowland/highland model for Latin American cattle ranching." J. of Historical Geography, April 1989.
[17] Teresa Rojas Rabiela, (coord.) *Agricultura indígena: pasado y presente.* Mexico City: Ediciones de la Casa Chata. 1994.
Gene C. Wilken. *Good Farmers: Traditional Resource Management in Mexico and Central America.* Berkeley: University of California Press. 1987.
Cynthia Radding. *Wandering Peoples: Colonialism, Ethnic Spaces, and Ecological Frontiers in Northwestern Mexico, 1700-1850.* Durham: Duke University Press. 1997.
[18] Wright, *Death* of *Ramon Gonzalez*, 122-123.
[19] Zimmerer, Karl S. *Changing Fortunes: Biodiversity and Peasant Livelihoods* in *the Peruvian Andes.* Berkeley: *University* of California Press. 1996.
[20] Christopher Wooley, "The Forests Cannot be Commons": Spanish Law, Environmental Change, and New Spain's Council on Forests." The Americas. V.77, 1, Jan 2020, 41-77.
[21] José Augusto Pádua, *Um Sopro de Destruicão: Pensamento politico e critica Ambiental no Brazil escravista (1786-1888) (Rio de Janeiro: Jorge Zahar) 2002*
[22]*Noble* Cook, *Born to Die: Disease and New World Conquest, 1492-1650.* Cambridge: Cambridge University Press. 1998.
[23] Melville.
[24]Teresa Rojas Rabiela, ed. *La agricultura chinampera.* Mexico City: Universidad Autónoma de Chapingo. 1983.
[25] Vera Candiani, *Dreaming of Dry Land: Environmental Transformation in Colonial Mexico City.* Palo Alto: Stanford University Press. 2014.
[26] Carl Sauer. "The Agency of Man on Earth." In *Man's Role in Changing the Face of the Earth* Wm. L. Thomas, ed. Chicago: University of Chicago Press. 1955.

[27] François Chevalier, *Land and Society in Colonial Mexico.* Berkeley: University of California Press. 1972.
David Brading, *Haciendas and Ranchos in the Mexican Bajío: Leon 1700-1860.* Cambridge: Cambridge University Press. 1978.
James Lockhart, "Encomienda and Hacienda: The Evolution of the Great Estate in the Spanish." Hispanic American Historical Review, 1969 49 31, 411-429. Lockhart emphasizes that many haciendas were completely rational economic enterprises based on the recognition of the economic values of diversity and of land held in reserve against changing social and economic conditions—as such, he invites a relatively optimistic view of its effects on biodiversity.
[28] Gary Nabhan, *The Desert Smells Like Rain: A Naturalist in Papago Indian Country.* San Francisco: North Point Press. 1982.
Rading, op. cit.

[30] Marcell A. Canuto, Francisco Estrada-Bell, Thomas G. Garrison, Stephen D. Houston, Mary Jane Acuña, "Ancient lowland Maya complexity as revealed by airborne laser scanning of Northern Guatemala." Science 28 Sept 2018 v.361,,6409.
[31] B. L. Turner, Jeremy A. Sabloff, "Classic Period collapse of the Central Maya Lowlands: Insights about human-environmental relationships for sustainability." PNAS Aug 28, 2012 109(35) 13908-13914.
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[32] The following discussion borrows from a rapidly developing literature. The best entry point is:
Susanna B. Hecht, Kathleen D. Morrison, Christine Padoch, eds. *The Social Life of Forests: Past, Present, and Future of Woodland Resurgence.* Chicago: University of Chicago Press. 2014. The entire volume is relevant in terms of newly developing analytical framework and theoretical perspectives, covering forests on several continents. Particularly relevant to the Amazon are, Susanna Hecht, "Rethinking Social Lives and Forest Transitions: History, Ideologies, Institutions, and the Matrix;" Susanna Hecht, "The Social Lives of Forest Transitions and Successions: Theories of Forest Resurgence;" John Vandermeer and Ivette Perfecto, "Paradigms Lost: Tropical Conservation under Late Capitalism;" Robin L. Chazdon, Braulio Vilchez Alvarado, Susan G. Letcher, Amanda Wendt, and U. Uzay Sezen, "Effects of Human Activities on Successional Pathways: Case Studies from Lowland Wet Forests of Northeastern Costa Rica;" Clark L. Erickson, "Amazonia: The Historical Ecology of a Domesticated Landscape;" Michael J. Heckenberger, Afukaka Kuikuro, Urissap'a a Tabata Kuikoro, J. Christian Russell, Morgan Schmidt, Carlos Fausto, and Bruna Franchetto, "Amazonia 1492: Pristine Forest or Cultural Parkland?"
[34] John Hemming, *Red Gold: The Conquest of the Brazilian Indians,* London: Papermac. 2nd ed. 1995.
[35] Heckenberger et al
[36] Anna C. Roosevelt, "The Amazon and the Anthropocene: 13,000 years of human influence in a tropical rainforest." *Anthropocene* v.4 Dec 2013 69-87.
[37] Heckenberger et al
[38] Richard Tucker, *Insatiable Appetite: The United States and the* Degradation *of the Tropical World.* Berkeley: University of California Press. 2000.

[39] Adrian Gustavo Zarilli, "Capitalism, Ecology and Agrarian Expansion in the Pampean Region (1890-1950)." Environmental History 6 (2002): 560-583.
[40] Wright, *Death of Ramon Gonzalez,* 146-151. This citation is to a brief account of liberalism and its consequences in 19th and early 20th century Mexico. Liberalism—here meaning market-oriented, classical economic liberalism, often now resembling what is usually termed neo-liberalism--held sway in most Latin American countries during this period, but each national story is, of course, different in context and consequences. In Argentina, for example, there were few peasant communities and traditions and relatively little landholding by the Roman Catholic Church, which made the entry into a liberal order easier and more thorough-going, without the resistance eventually expressed in the Mexican Revolution of 1910-1920—nationalist reaction in Argentina would take longer to organize itself politically. In Argentina and Brazil, even more so than in Mexico, liberals enjoyed the active support of British financiers and the British government. These varying histories of liberalism and its consequences may be found it most standard histories of Latin America, but the biological implications have been largely unexplored in spite of major obvious implications.
[41] Latin America continues to be highly dependent on relatively small family farms for domestic food supplies. The literature is plagued by data problems and is also a highly polarized discussion. An excellent article that recognizes and discusses the sources and major data problems is, Benjamin E. Graeub, M. Jahi Chappell, Hannah Wittman, Samuel Ledermar, Rachel Benzer Kerr, Barbara Gemmill-Herren, "The State of Family Farms in the World." *World Development,* v87no.206, 1—15. The authors show that the world is primarily dependent on family farms for food needs.
[42] Christopher R. Boyer, *Political Landscapes: Forests, Conservation, and Community in Mexico.* Durham: Duke University Press. 2015.
[43] Irineu de Carvalho Filho, Leonardo Monasterio. "Immigration and the origins of regional inequality: Government sponsored European immigration to Brazil before World War I." *Regional Science and Urban Economics.* V42,5, S.2012, 794-807.
[44] Tucker, *Insatiable Appetite, ch.6*
Angus Wright and Wendy Wolford. *To Inherit the* Earth*: The Landless Movement and the Struggle for a New Brazil.* Oakland, California: Food First Books. 2003. Ch.3.
Henri Acselrad, *Conflitos Ambientais no Brasil. Ch.2,3.*
[45] Jacques Leslie, *Deep Water: the epic struggle over dams, displaced people, and the environment.* New York: Farrar, Straus and *Giroux*. 2005.
[46] Wright, *The Death of Ramon Gonzalez.*
[47] Jeff Mitchell. *The Avocado: A Global History.* London: Reaktion Books. 78-83.
[48] José Paulo Pietrafesa and Sandro Duarte e Silva. *Transformações no Cerrado, Progresso, Consumo e Natureza.* Goiánia, Brasil: Editora da PUC Goiás.
[49] Antonio M.Buainan, Rodrigo Lanna, Zander Navarro. *Agricultural Development in Brazil: The Rise of a Global Agro*-Fuel *Power.* Oxon and New York: Routledge. 2019.
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[53] Liberty Vittert, *The Conversation,* "Statistic of the Decade: The Massive Deforestation of the Amazon." D.23, 2019.
[54]Perfecto et al, Nature's *Matrix,* 161-190.
[55] Ibid, 191-206.
[56] Antonio Augusto Rossotto Ioris, *Tropical Wetland Management: The South American Pantanal and the International Experience.* New 2 and London: Routledge. 2016.
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[58]Zimmerer, *Changing Fortunes.*
[59] Perfecto et al, *Nature's* Matrix, *esp.* chs 1-3.
[60] Stephen R. Gliessmann, E.R. Garcia, and A.M. Amador. "The ecological basis for the application of traditional agricultural technology in the management of tropical agro-ecosystems. *Agro-ecosystems 7:173-185.*
Gene Wilkins, *Good Farmers.* Wright and Wolford, *To Inherit the Earth,* 288-294.
[61] Wright and Wolford, 288-294.
[62] Graeub, et al, "The State of Family Farms in the World."
[63] Andrea A. Azevedo, Raoni Rajão, Marcelo A. Costa, Marcelo C. C. Stabile, Marcia N. Macedo, Tiago N.P. dos Reis, Ane Alencar, Britado S. Soares Filho, Rayane Pacheco. "Limits of Brazil's Forest Code as a means to end illegal deforestation." PNAS July 2017 v114n29, 7653-7658.
Jason Daley, "Amazon Deforestation Has Increased Dramatically this Year." *Smithsonian* July 2, 2019.
[64] Cf. Chase D. Mendenhall, Analisa Shields-Estrada, Arjun K. Krishnaswami, Gretchen Daily. "Quantifying and sustaining biodiversity in tropical agricultural landscapes" PNAS D.20, 2016 113(51) 14544-14551.
Perfecto et al, *Nature's Matrix*
[65] Ibid, ch. 7
[66] Webpage of the Latin American Scientific Society of Agroecology. See, also, IAASTD: Latin America (footnote 1)
[67]Perfecto et al, *Nature's Matrix*, 9-13.