

***The Modern World-System* as environmental history? Ecology and the rise of capitalism**

JASON W. MOORE

*University of California, Berkeley*¹

Abstract. This article considers the emergence of world environmental history as a rapidly growing but undertheorized research field. Taking as its central problematic the gap between the fertile theorizations of environmentally-oriented social scientists and the empirically rich studies of world environmental historians, the article argues for a synthesis of theory and history in the study of *longue duree* socio-ecological change. This argument proceeds in three steps. First, I offer an ecological reading of Immanuel Wallerstein's *The Modern World-System*. Wallerstein's handling of the ecological dimensions of the transition from feudalism to capitalism is suggestive of a new approach to world environmental history. Second, I contend that Wallerstein's theoretical insights may be effectively complemented by drawing on Marxist notions of value and above all the concept of "metabolic rift," which emphasize the importance of productive processes and regional divisions of labor within the modern world-system. Finally, I develop these theoretical discussions in a short environmental history of the two great "commodity frontiers" of early capitalism – the sugar plantation and the silver mining complex.

Recent years have witnessed something of a renaissance for world-historical studies.² This is especially true for world environmental history. Barely on the radar just a few years ago,³ ecologically-oriented world history has become an important field of inquiry for a small but growing number of scholars.⁴ In contrast to an earlier wave of world-historical studies, however, world environmental history has remained largely the province of historians, and they have been generally reluctant to engage social theory. The result? A strongly historical but weakly theoretical current at one pole and a robust theoretical-methodological but inadequately historical movement at another. The environmental historians don't quite know what to do with social theory, and the environmentally-oriented social scientists don't quite know how to translate their perspectives into historical research.⁵ For world environmental history, the relative absence of cross-fertilization between the two poles poses particularly grave problems. Chief among these are questions of geography. The enterprise of world history, more so than local and regional history, poses difficult theoretical questions relating

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to, among other things, the nature of what constitutes a “world,” and the (ever-shifting and equally vexing) relations between “global” and “local” space.

To be sure, there is no shortage of sophisticated theoretical approaches to nature-society relations within the social sciences: O’Connor’s “second contradiction” thesis; actor-network theory and other critiques of nature-society dualisms, largely clustered around a broadly defined “political ecology” perspective; Foster’s theory of metabolic rift; and many more.⁶ Nor is there a dearth of rigorously empirical world environmental histories: McNeill’s study of twentieth-century environmental history; Davis’s accounting of famine, ecology, and imperialism in the late nineteenth century; Grove’s groundbreaking work on European colonialism and the origins of conservationism, to name a few.⁷ But there awaits a synthesis of theory and history for the study of large-scale socio-ecological change over the *longue duree*.

This article offers a way of thinking through this synthesis problem in two steps. First, I look for answers by turning to what may seem an unusual source, Immanuel Wallerstein’s *The Modern World-System I: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century*.⁸ Wallerstein’s pioneering study of the transition to capitalism in the “long” sixteenth century (1450–1640) has been read universally and debated through the lens of “human exceptionalism,” to borrow a phrase from the founders of environmental sociology.⁹ Even among world-systems analysts, Wallerstein’s work is widely characterized as a rupture with Braudel’s emphasis on the physical environment.¹⁰ We learn here that, contrary to conventional wisdom, ecological concerns, far from absent, are in fact central to *The Modern World-System*. Wallerstein’s analysis of the crisis of feudalism and the rise of capitalism pivots on socio-ecological factors, including soil exhaustion and its relation to monoculture and to the biological fate of the direct producers, soil erosion from excessive grazing, agronomic choice and the trajectories of Chinese and European civilizations, epidemiology and its relationship to the introduction of European livestock to the Americas, climate change, deforestation and timber scarcity, and the relation of dietary regimes to capitalist development.

What kind of world environmental history does *The Modern World-System* suggest? Our second step towards theoretical-historical synthesis puts Wallerstein’s eco-historical approach to the test. Focusing on the great “commodity frontiers” of early modern capitalism – sugar

plantations and silver mining – I show that Wallerstein’s socio-ecological insights, coupled with Marx’s ecological critique of capitalism, prove enormously useful for rethinking environmental transformations in world-historical perspective. The sugar and silver commodity frontiers were not only economically central to the emergence of a modern world-economy, as Wallerstein contends. Equally, they were *ecologically* central, constitutive moments of an epochal reorganization of “world ecology.”¹¹ In various ways, silver and sugar enabled the emergence of far-flung divisions of labor and the consolidation of a capitalist world-economy predicated on the endless accumulation of capital. The “local” environmental transformations precipitated by these frontiers were not simply *consequences* of European expansion; they were in equal measure constitutive of such expansion, condition as well as consequence. Degradation and relative exhaustion in one region after another were followed by recurrent waves of global expansion aimed at securing fresh supplies of land and labor, and thence to renewed and extended cycles of unsustainable development on a world-scale.¹²

What I am proposing, then, is to revisit *The Modern World-System* for its suggestions about how we might work through, at once historically and theoretically, the relations of capital, class, and nature in the origins of the modern world. This necessarily entails a restatement and amplification of Wallerstein’s accounting of the transition to capitalism. My intent, however, is not to rehabilitate this account in all its particulars, much less to defend all the particulars of world-systems analysis. Rather, this consideration of *The Modern World-System* seeks to illuminate how an *apparently* conventional “human exemptionalist” framework was synthesized with ecological materialist sensibilities, and how this synthesis might be deepened and extended for the study of large-scale socio-ecological change. My appraisal of Wallerstein’s effort emphasizes the ways this approach at once undermines and encourages the environmental history of capitalism. Thus, an ecohistorical reading and critique of *The Modern World-System* forms the basis for the historical-geographical sketch of European expansion and environmental transformation that follows.

Immanuel Wallerstein, environmental historian?

“[F]actors of the physical environment . . . should be assessed and given their due weight . . . [I]ntruding the variables of the physical environment does not undo our previous [social] analysis. It enriches it by adding a further element to help explain a historical conjuncture so consequential in the future history of the world.”¹³

Among environmentally-inclined world-systems analysts and globally-oriented environmental historians, a certain consensus holds. However useful *The Modern World-System* may be for matters of large-scale economic history, it is silent on the environment.¹⁴ In *The Modern World-System*, argues Sing Chew, “the ecological dimension that was part of the Braudelian framework [was] dropped.”¹⁵ In contrast to Braudel’s ecohistorical method, Wallerstein focused exclusively “on the ways of organizing relations among humans.”¹⁶

Curiously absent from these evaluations is a serious engagement with the text itself. A closer reading of *The Modern World-System*, I suggest, points to the volume’s strong ecohistorical content, and its importance for conceptualizing a world environmental history that highlights capitalism’s historical-geographical specificity. Above all, *The Modern World-System* deserves a careful re-examination for its profoundly suggestive treatment of agro-ecological transformations in the transition from feudalism to capitalism. While feudalism’s agro-ecological contradictions were widely recognized prior to the mid-1970s,¹⁷ Wallerstein’s innovation was to link these contradictions to the emergence of capitalism, itself the agent of new and far-reaching ecological transformations.

Although lacking a systematic accounting of ecological factors in the emergence of capitalism, Wallerstein’s account and method sheds more light upon the ecological moment of the transition than is commonly acknowledged. The widely circulated critique of Wallerstein as a “circulationist”¹⁸ has obscured the volume’s strong materialist and historical-geographical content. A more careful reading of *The Modern World-System I* reveals something quite different from the circulationist label – something much closer to Marx’s even-handed approach to the dialectics of market, nature, and production.¹⁹

The Modern World-System is remarkable in two respects – one sociological, the other geographical. In the first instance, it is a perceptive study of how world market formation shaped, and was shaped by, regional patterns of class conflict, state formation, and associated modes of agricultural production – all of which were undergoing profound transformations precisely because feudalism’s ecohistorical limits had been reached.

This world-historical *sociology* is complemented by a world-historical *geography*. Contrary to one of the stock criticisms of the world-systems

perspective,²⁰ Wallerstein's handling of the local-global dialectic reveals a sophisticated tension between scales rather than a simplistic global determinism. Indeed, *The Modern World-System* is very smart about space. Rather than beginning with an abstract spatial entity (such as the nation-state, or even "Europe"),²¹ for instance, Wallerstein emphasizes the production of space in ways that prefigured later Marxist theorizations of uneven development.²²

Four moments of Wallerstein's historical geography of the transition to capitalism deserve special attention: equalization, expansion, divergence, and agro-ecological transformation. First, there was a process of *equalization* across space. Through the production of a new geographical scale – the capitalist world-economy – Europe's leading strata brought together formerly isolated or only loosely-articulated areas into a single division of labor. This new world-economy took shape as medieval Europe's multiple smaller world-economies merged, above all in the North Sea and the Mediterranean.²³ We can speak of equalization because the socio-ecological relations encompassed by the new capitalist world-economy were increasingly (if unevenly) subordinated to the equalizing (and homogenizing) tendencies of commodity production – *generalizing* if not yet *generalized* – mediated through a competitive world market.

Second, there was a process of *expansion*. Geographical expansion, above all into the Americas, was essential to the resolution of feudal crisis in a way favorable to capitalist development. Even at this early date, the imperative of ceaseless geographical expansion emerges as the spatial corollary of ceaseless capital accumulation. The expansion of the scale of the world-economy was reinforced by the consolidation and expansion of the scale of the territorial states and their empires that had suffered during the feudal crisis but gained renewed vigor through overseas expansion.

Third, as widely noted, there was a process of *divergence*. A new globalizing relation between core and periphery took shape, initially between eastern and western Europe, and between western Europe and the Americas.

Finally, there was *agro-ecological transformation*. The rise of capitalism was part and parcel of a radical reshaping of world ecology, whose most dramatic features were found in the new American and eastern European peripheries.

Although the first three aspects of Wallerstein's historical geography are well known, the fourth is not. I propose to address these three moments of uneven development through this fourth optic, agro-ecological transformation. In this article, we explore the ways that the emergence of a pan-European world-economy, stretching from the Baltic to the Americas, was at once cause and consequence of an epochal reorganization of world ecology. On the one hand, the emergence of capitalism as a response to feudal crisis by Europe's ruling strata was conditioned by the ecological contradictions of the feudal system, such as declining soil fertility. On the other hand, the likelihood of a successful transition to capitalism, rather than a reversion to feudalism or a world imperium, was itself predicated on the widening and deepening transformation of the earth so as to favor the generalization of commodity production.

Wallerstein's world-historical sociology and world-historical geography are dialectically bound by an ecohistorical interpretation of feudal crisis and capitalist transition. This interpretation is crystallized in his apt formulation of:

1. the crisis of feudalism as a "socio-physical" conjuncture;²⁴ and
2. the emergence of capitalism as an epochal reorganization of "world ecology."²⁵

We may consider these two ecohistorical moments – one central to the crisis of feudalism, the other central to the emergence of a capitalist world-economy – in their respective turns.

Linking the socio-ecological crisis of feudalism with capitalism's reorganization of world ecology is Europe's geographical expansion. From Wallerstein's standpoint, feudalism's class contradictions in the crisis years of fourteenth and fifteenth centuries favored such expansion, which allowed medieval Europe's ruling strata to recoup its economic losses without engaging in a costly and perhaps fruitless struggle to reimpose serfdom on western Europe's insurgent peasantries. Naturally, if geographical expansion was to serve this purpose, it had to be profitable. The extension of the commodity production to frontier zones (silver, sugar), at first in the Atlantic islands and then in the Americas, was the decisive moment of world ecological reorganization. Reading *The Modern World-System*, we learn that the processes of capitalist widening and deepening made possible, and *were made possible by*, radical and far-reaching environmental transformation,

necessitating yet further geographical expansion in a ceaseless quest for uncommodified supplies of land and labor.

*The political ecology of feudal crisis*²⁶

Let us begin with the crisis of feudalism as “socio-physical” conjuncture. Wallerstein proposes that the “feudal system of social organization” could advance only so far before encountering insuperable limits. A system based on the political extraction of surplus offered few incentives for increased productivity. Because peasant surpluses were vulnerable to seizure by the seigneurs, feudal property relations tended to limit the surplus available for investment in agricultural improvement. Economic expansion was therefore largely contingent upon geographical expansion. Seigniorial revenues increased as long as the population continued to grow, which meant that the amount of land under cultivation tended to expand, all other things being equal. And this was precisely the case between the eleventh and later thirteenth centuries.

Around 1300, however, feudalism appears to have overstepped the socio-ecological limits to continued expansion. The feudal organization of agriculture had begun to exhaust its land and labor power in the European heartland, and yield ratios (already quite low by the era’s world standards) stagnated or even declined. Meanwhile, settler expansion had brought more and more people onto less and less productive land at the geographical margins of the system. The margin of survival for European peasant agriculture was always razor thin. Relative overpopulation in the heartland, alongside overextension at the margins, undermined soil fertility and rendered fourteenth-century agriculture vulnerable to climate change. The agrarian recession of the later thirteenth century was already in motion prior to any epochal environmental shifts. But small shifts of any kind during periods of socio-ecological stress can produce big changes. In this sense, Wallerstein counts the arrival of chilly weather among the “cumulative woes” that “dealt a crushing blow to the already fragile demographic structure” of European feudalism.²⁷

Also among feudalism’s cumulative woes was epidemic disease. The decisive moment in the crisis of feudalism was the coming of the Black Death in 1348. The catastrophic impact of the Plague can be traced to “the chronic factor of resource strain involved in the feudal system of

social organization.”²⁸ Late feudalism’s eco-geographical overextension and overexploitation not only rendered agriculture highly vulnerable to climate change. It biologically impoverished the peasantry. Malnutrition rendered the mass of the population vulnerable to disease. In a system where the social reproduction of the ruling class hinged upon a growing population in order to sustain seigneurial revenues, the Black Death quickly transformed the agrarian depression of the early fourteenth century into a terminal crisis of the feudal system.

At base, the crisis of feudalism was one of declining seigneurial revenues, owing to the demographic decline and the resulting enhanced bargaining position of the peasantry. The competitive pressures that had previously favored the seigneurs, in an era of demographic expansion, now favored the peasants. The crisis of the seigneurs led in short order to the crises of the political institutions of Europe, especially the territorial states and the Church. This was also a moment of crisis for capitalists based in the city-states, who faced declining returns on trade and manufacturing, as the agrarian base of European civilization crumbled. The conjuncture of these multiple crises would play a key role in the resolution of feudal crisis – a crisis that, as we know, resulted in the transition to capitalism rather than to another tributary system.

Wallerstein’s analysis of the transition pivots on the relation between class structure and the labor-land ratio. Where population density and urbanization remained *relatively* high, as in western Europe, the peasantry’s power was augmented proportionately. If the west’s population density was still higher than the east’s, after 1348 it was still much lower than it had been. The upshot? The feudal equivalent of the “reserve army of labor” was effectively dissolved, and the seigneurs now had to bargain with the peasantry much more seriously than ever before.²⁹ The new balance of class forces in western Europe, therefore, favored the rise of the yeoman farmer and intensive agriculture, although not in all regions, and not always to the same degree. Here, the peasantry’s class power precluded the reimposition of serfdom, which in the short run exacerbated the ongoing crises of western Europe’s ruling strata. Where population density and urbanization was relatively low, as in eastern Europe and the Americas, extensive agriculture developed on the basis of “coerced cash-crop labor” (serfdom) or outright slavery. This difference was the result at once of the differential possibilities for “*effective* resistance,” owing to varying degrees of urbanization and population densities, and of the differ-

ential commercial opportunities presented by the relative availability of land: “If there is plenty of land, one can make do with relatively inefficient means of production. One can engage in extensive agriculture. One can use slaves or coerced cash-crop laborers [serfs].”³⁰

The intensification of western European agriculture and the spread of extensive, cash-crop agriculture in eastern Europe and the Americas were complementary processes. The spread of coercive modes of labor control in the new peripheries – especially slavery in the Atlantic and the “second serfdom” in eastern Europe – was possible to the extent that a significantly larger world market for cereals and sugar emerged in the fifteenth and sixteenth centuries. But this larger market could develop only on the basis of industrialization and agricultural innovation in the emergent core regions. High value-added industrial and agricultural sectors, in the Low Countries for instance, were sustainable only insofar as reliable grain supplies could be obtained for the cities.³¹ Moreover, industrial expansion required horse-power, which meant that arable land had to be converted to pasturage, which meant that workers had to be fed with (still more) imported grain. Rising core demand for grain, in turn, sent prices and profits upwards, which tended to lock the peripheral Baltic into an expanding world-scale division of labor.³² “Hence, the process of agricultural innovation fed rather than foreclosed the necessity of expansion.”³³

The centrality of geographical expansion

Geographical expansion was not only necessary – that is, necessary if the feudal crisis was to be resolved in favor of capitalist transition – but practical. It was necessary because the possibilities for inner expansion³⁴ were limited – not by population but by social structure; outer expansion in contrast was practical because of the proximity of the Atlantic islands and the Americas, and feasibility of cash-crop production in these new areas. The central problem was not too little land but too much:

There was physical room for the population, even the growing population. *Indeed that was part of the very problem that led to expansion.* The physical room was one element in the strength of the peasantry vis-à-vis the nobility, and hence one factor in the decline of seigniorial revenues, in the crisis of feudalism.... What the nobility (and the bourgeoisie) needed ... was a more tractable labor force. The size of the population was not the issue; it was the social relations that governed the interaction between the upper and lower

classes.... Europe needed a larger land base to support the expansion of its economy, one which could compensate for the critical decline in seigniorial revenues and which could cut short the nascent and potentially very violent class war which the crisis of feudalism implied.³⁵

Transatlantic expansion was the path of least resistance, given the reality of overlapping crises, pushing together interests that had hitherto been at odds. Because it had empowered the peasantry, the feudal crisis created significant common ground among Europe's ruling strata – the states, the seigneurs, and the city-state capitalists – in favor of “outer” rather than “inner” expansion. “The only solution that would extract western Europe from decimation and stagnation would be one that would expand the economic pie to be shared, a solution which required, given the technology of the time, an expansion of the land area and population base to exploit.”³⁶

Wallerstein shows that the creation of a capitalist world-economy was the outcome of a conjuncture of crises through which the interests of these three major groups – the territorial states, the seigneurs, and the city-state capitalists – converged to favor overseas expansion. *First*, the territorial states, which had made great strides between the eleventh and fourteenth centuries – owing to increased revenues from “internal” expansion and the politico-military unification that resulted from the Crusades – now suffered greatly from the economic contraction that began even before the Black Death. Beginning in the fourteenth century, the territorial states faced a deepening “liquidity crisis” as they struggled to exact higher taxes from the peasants in the interests of waging war.³⁷

Second, the seigneurs faced a deepening crisis in the wake of the Black Death. The downward readjustment of labor-land ratios effected several crucial changes in the balance of social forces, particularly in western Europe. First, the economic contraction in the countryside, which began in the later *thirteenth* century, led to rising social unrest. Peasant revolts grew more frequent, and extended their theater of operations from villages to larger regions. Urban unrest increased as well, which tended to strengthen peasant movements.³⁸ Second, once population contraction set in, at first slowly through the increasing frequency of famine and then rapidly with the coming of the Black Death, revenues declined. Third, as we noted earlier, declining population led to increased competition among the seigneurs for peasant labor.

In this situation, an internal fix (that is, internal to Europe) of the seigneurial crisis was hardly a possibility, given the widespread abandonment of villages and cultivated land in the wake of the Black Death. Whatever inner expansion occurred was very largely an expansion of pasturage rather than arable land, a move that militated against a rapid population recovery.³⁹ Sheep farming especially not only required fewer hands relative to agriculture, it yoked the seigneurs to the world market, who were as a consequence inclined to support measures that favored the further expansion of that market. The resulting widespread displacement of cereal agriculture by animal husbandry not only entailed a deepening of the world-economy's division of labor, but biased it in favor of further expansion. It was no mere coincidence that Castile, itself one of the two great sheep farming areas of Europe, led the conquest of the New World and established sheep farming almost immediately upon arrival. "[S]heep ate men, in middle America just as in England."⁴⁰ And it was not only Europeans who were "eaten" by sheep and other livestock. Indian cultivation directly suffered from trampling livestock, an important contributing factor to their great demographic collapse of the sixteenth century.⁴¹

Meanwhile, owing to rising seigneurial competition, declining revenues, and relatively high urbanization after the Black Death, western Europe's peasantry waged the class struggle much more effectively than heretofore, squeezing the seigneurs, who in turn squeezed the states, who were forced to recognize the former's voice in policy-making. Ultimately, the seigneurs could expand their revenues only as far as "their" states prospered, and during the crisis of feudalism such prosperity was limited to the extent that inner expansion was privileged over outer expansion – precisely because of the peasantry's strength. Thus an uneasy compromise prevailed, one ultimately resolved in favor of territorial state power and overseas expansion.

Third, the city-states also experienced particular and general contradictions that favored geographical expansion. Presumably, the city-state capitalists faced a contracting market once seigneurial revenues began to decline. Pushed out of the eastern Mediterranean by Venice, Genoa provided the capital necessary for Iberian expansion.⁴² And it didn't hurt that geographical expansion "minimized ... [the] potential for internal disorder ... [posed by the] urban semiproletariat."⁴³

The political ecology of the transition to capitalism

The convergence of interests in favor of overseas expansion favored the transition to capitalism. In the abstract, however, expansion tells us little about the capitalist reorganization of world ecology. European expansion was also a process of consolidation that brought together the existing North Sea and Mediterranean world-economies into a relatively unified division of labor.⁴⁴ Even without an immediate increase in agricultural productivity, the enlarged scale of the new world-economy provided its ruling strata with a greatly enlarged resource base. This integration of Europe's world-economies was complemented by geographical expansion and core-periphery polarization. Not only the economic surplus, but also the *ecological surplus*, that derived from Europe's expanding division of labor was "unequally consumed."⁴⁵ European capitalism's resource base was not only *absolutely* larger than its predecessor world-economies. Thanks to the inequalities and incentives built-in to capitalist development, it was *relatively* larger. Much larger.

American bullion was possibly the most important of these resources. Among the more intriguing aspects of Wallerstein's interpretation of American bullion's importance to the emergent world-economy is its ecological dimension. Why was bullion so important to the "vast but weak" world-system? "It sustained the thrust of the expansion, *protecting this weak system against the assaults of nature.*"⁴⁶ Gold and silver protected the original accumulation of capital against the devaluing impact of poor harvests. Would Braudel's "Age of the Genoese"⁴⁷ have been possible without bullion to lubricate the trade between northern and southern Europe, and to insure Genoa against the threat of famine?⁴⁸

Equally important in "protecting this weak system against the assaults of nature" were New World crops. Here is the flip side of Crosby's (1986) "ecological imperialism." By itself, Europe's biodiversity was probably insufficient to sustain its subsequent population growth. "Without the American crops, Europe might not have been able to carry such heavy populations as she later did, and the Old World tropics would not have been so quickly developed."⁴⁹

For Wallerstein, "the thrust of [European] expansion" arose from the ascendant logic of capital accumulation under conditions of resource strain⁵⁰ – conditions largely created by capital's ascent and feudalism's

dissolution. “What western Europe needed in the fourteenth and fifteenth centuries was food (more calories and a better distribution of food values [in favor of the emergent core]) and fuel.”⁵¹ The drive for fuel and food – especially wood, wheat, and sugar – reinforced capital’s tendency toward uneven development, in the case of western and eastern Europe transforming the latter’s small differences into large and durable inequality,⁵² and creating new peripheries in the Atlantic islands and the Americas.

This development of an unequal world division of labor, in turn, was cause and consequence of new competitive pressures toward specialization between arable and pasture, and between agriculture and industry. Predictably, these processes encouraged capitalist monoculture and the prioritization of short-run profits over sustainability. In England, “the orientation of these town bourgeois was toward short-run profit ... which had the effect of desolating the land over the following [sixteenth] century.”⁵³

In Spain, a similar process was ongoing. Triennial rotations were forsaken, leading to soil exhaustion. “This situation led, in the years from 1570 to 1630, to the search for new domains, which were then similarly exhausted.” Wallerstein’s analysis gets more interesting from this point, however. It turns out that not only did primitive accumulation lead to ecological degradation. In Spain, ecological degradation could lead to renewed primitive accumulation:

[The] “aridification” of the land hit particularly the small producers and led to further land concentration. While this process of exhausting the land led to inability to export, land concentration that resulted from it led to a further *monetarization* of productive relations, since “the inability of peasants ... and villagers to provide for their own subsistence by working their own land enlarged the internal market.”⁵⁴

Next to food, forest products were “the other great basic need” in the early modern world-economy. Alongside sugar, they were the era’s “continuing ‘growth’ crop.”⁵⁵ England’s invasion and subsequent colonization of Ireland after 1600 was ecologically as well as socially devastating. Ireland’s “woods were used up to supply England with timber,” as well as to deprive resisters of forest cover from English cavalry.⁵⁶ Whereas one-eighth of the Emerald Isle was forested in 1600, it had “virtually disappeared by 1700.”⁵⁷ In Spain, the forests receded under the pressure of a rising sheep population that was a direct response to growing world market demand.⁵⁸

In the sixteenth-century Mediterranean, the “wood famine” was so great that “Nordic wood arrived in Seville with boats filled to the brim with planks and beams.”⁵⁹ Growing demand led inexorably to the “slow but steady deforestation of western Europe, Italy, and Spain, as well as Mediterranean islands. Oak became especially scarce.”⁶⁰ In France, the iron industry’s devastation of forests sparked peasant revolts by the 1730s.⁶¹ Dwindling timber supplies in the core and semiperiphery led to the expansion of what we might call “cash-crop” forestry in the Baltic region, which by “the sixteenth century ... had begun to export wood in large quantities to Holland, England, and the Iberian peninsula.”⁶² As a consequence, by the time of the Thirty Years’ War (1618–48), itself a major source of “ecological stress,”⁶³ the “reckless exploitation” of Poland’s forests had “produced a desert in the woods.”⁶⁴

Perhaps most important is the case of sugar. “Unlike wheat, cattle, and silver, sugar was not involved in the problem of oversupply” in the early modern world-economy.⁶⁵ Wallerstein links together: 1) the production of peripheral space and degraded landscapes through the plantation system; 2) the degradation of the soil and the expansion of the world-economy; and 3) the degradation of the soil and the degradation of the worker. In the first instance, Wallerstein argues that the trend toward monoculture was most evident in the periphery. Plantation-driven monocultures were the most dramatic, and quite possibly the most important, way that peripheral landscapes were produced in the emergent capitalist world-economy. “The trend in the *core* was towards variety and specialization [in high value-added crops], while the trend in the periphery was toward monoculture.”⁶⁶

Secondly, sugar’s “eternal problem was ecological exhaustion and the necessity to find virgin zones to exploit.”⁶⁷ In a passage that seriously undermines the critique of circulationism directed against Wallerstein, he explicitly rejects Pierre Chaunu’s economic explanation of Brazil’s early seventeenth-century sugar revolution in favor of an ecological one:

Is it not easier to explain this expansion by the previously discussed relationship between the fairly rapid rate of ecological exhaustion and world demand and conclude that as a product of the world-economy, sugar was less subject to secular swings than were wheat and silver?⁶⁸

Thirdly, Wallerstein sees a dialectical connection between the degradation of the soil and the degradation of the worker: “The [largely sugar] monocultures imposed on the Mediterranean and Atlantic islands

ravaged them, pedologically and in terms of human population. Their soils were despoiled, their populations died out.”⁶⁹ With sugar, we have a “very lucrative and demanding product, pushing out wheat but then exhausting the soil, so that it required ever new lands (not to speak of the manpower exhausted by its cultivators).”⁷⁰ In *The Modern World-System II*, Wallerstein extends this thinking to eastern Europe’s agricultural crisis in the early seventeenth century: “Production was increased ‘by deviating from the fundamental principles of rotation in tilling the soil,’ which over time exhausted the soil. Exhausting the *men and the soil* maintained a level of total production for 50–60 years, but it was a self-containing [and self-defeating!] method.”⁷¹

In both cases (sugar and wheat, but especially sugar), Wallerstein links capitalism’s degradation of the soil with the degradation of the worker. For Wallerstein, as for Marx,⁷² the transformation of nature *is* a labor process. The degradation of nature *is* the degradation of the worker, and occurs *only through* the degradation of the worker under the law of value.⁷³

For now, it bears emphasizing that this degradation of the worker could occur both at the point of production and through the instrument of world trade – through relations of production and relations of consumption (socio-biological reproduction).⁷⁴ Capitalist enterprise in the Americas was enormously destructive of labor: “sheer exhaustion of manpower, especially in the mines, must ... have been significant.”⁷⁵ The same could be said of sugar cultivation – the relatively low cost of slave labor was perfectly suited for sugar, whose (generally) low skill requirements were matched by equally high mortality rates, high even by the standards of New World slavery. Hence, the ecologically-driven westward movement of sugar, first to the Atlantic islands and thence to the Americas, led to the emergence of a new, capitalist, and racialized slave regime based on African laborers. But why Africans as the new slaves? Because in Africa, capitalists found a nearby area from which it could extract slaves with little concern for its regional socio-ecological implications.

It was not only slaves who suffered bodily in the transition to capitalism, however. In terms of European diet, the shift from arable to pasturage at the beginning of the long sixteenth century (1450–1640) assumes added importance. The Black Death reduced labor-land ratios, and thereby allowed for more land per capita. This should have allowed for a fairly rapid demographic recovery, all other things being

equal. But equal they were not. “[A]lthough fewer men should have meant more food since the landmass remained the same, it also meant a shift to pasturage and hence a reduction of caloric output.”⁷⁶ This reduction was of course unequally distributed. “European workers paid part of the costs of European economic development” through a deteriorating diet.⁷⁷ Europe experienced a “partial ‘decerealization’ ... in favour of animal husbandry ... [thereby] altering the pattern of consumption,” which among other things meant that the bulk of the population suffered “scarcely less than previous centuries from death and famine.”⁷⁸

The most important thing to note about pasturage in the sixteenth century, especially livestock, was that it was becoming increasingly a regionally specialized activity. *More cattle here, an advantage to large landowners, also meant less cattle elsewhere, which often meant a reduction in peasant consumption of meat and dairy producers, a deterioration in the diet.*⁷⁹

A new dietary regime was therefore one means by which bodily space was articulated with the broader town-country division of labor in the transition to capitalism.

The Modern World-System I: Promise and perils for world environmental history

We might crystallize Wallerstein’s approach to world environmental history into three broad contributions. First, he establishes the historical-geographical specificity of nature-society relations in successive epochs of European history. *The Modern World-System* makes a good case that something significant was changing in nature-society relations between the “long” fourteenth century and the “long” sixteenth century, and that this had something to do with the rise of capitalism. Feudalism, as we have seen, had its share of ecological problems. (On this basis, it is exceedingly unlikely that Wallerstein would deny ecological degradation as a significant factor in all manner of non-capitalist systems.) What Wallerstein highlights is the historical-geographical specificity of feudalism’s socio-ecological contradiction, namely, its tendency to limit investment in the soil, thereby generating a long-run tendency toward soil exhaustion. Although this insight did not originate with Wallerstein, he was the first to relate this contradiction to the many-sided general crisis of feudalism and the ensuing transition to capitalism. In contrast to leading studies of long-run, world environmental history,⁸⁰ Wallerstein *explains* the change in

nature-society relations as the unintended outcome of feudalism's social and ecological contradictions. He discusses early capitalism's emergent socio-ecological logic in terms that have special resonance today, including the world-historical relations of monocultural production, unsustainable economic development on a regional scale, dietary regimes, and labor systems destructive to land and laborer alike. Perhaps most fundamentally, *The Modern World-System* strongly suggests that, where feudalism generated regional ecological crises, the rise of capitalism generated ecological problems increasingly global in scope.

Wallerstein's second major contribution is an explicit rendering of the dialectical connection between world-economy and what I would call *world-ecology*. The crisis of feudalism, recall, can be explained partly in terms of a "socio-physical conjuncture,"⁸¹ in which ecological conditions were both produced and given. The rise of capitalism was predicated on an epochal reorganization of "world ecology." Here, then, is the embryo of an ecological theory of imperialism, whereby "world ecology was altered and in a way which, because of the social organization of the emergent European world-economy, would primarily benefit Europe."⁸² (And the European core above all!)⁸³ What I think merits amplification is the linkage of "world ecology" with the rise of capitalism. Are we not here dealing with the "production of nature" in a thoroughly world-historical sense? The agro-ecological transformations of the long sixteenth century signaled not only the rise of a capitalist world-economy but equally the emergence of a capitalist *world-ecology*. What may seem a trivial terminological maneuver is intended to illuminate a substantive *problematique*. With the rise of capitalism, local ecologies were not only transformed by human labor power (itself a force of nature), but brought into sustained dialogue with each other. The interaction of multiple local and regional ecologies became far more than the total of their respective parts, as capitalism began to create a new relational universe for ecosystems no less than social actors. From this standpoint, neither ecology nor society, strictly speaking, is "context." Rather, the rise of a capitalist world-economy and the rise of a capitalist world-ecology were two moments of the same world-historical process. This "separation in unity" (as Marx would say) constitutes a dialectical antagonism between capitalism's drive to accumulate endlessly and the demands of ecological sustainability.

Finally, I think Wallerstein approaches nature-society relations in a way that is somewhat more productionist than critics or comrades typically acknowledge.⁸⁴ If Wallerstein does not strike precisely the right balance of production and exchange in *The Modern World-System*, he nonetheless offers insight into environmental transformations that often effectively balance labor and class relations with the development of a capitalist world market. Recall his arguments about the relation between ecological degradation and primitive accumulation in sixteenth-century Spain, or between the exhaustion of the soil and the laborer in early seventeenth-century Poland, or between monoculture and slavery in the sugar islands. The contrast with recent world environmental history approaches is instructive. In Hughes's *An Environmental History of the World*, for instance, a "world market economy" becomes the main engine of modern world-ecological change.⁸⁵ Others privilege technological change (abstracted from production relations), population dynamics, ideological structures, or some combination thereof, with little effort to pierce the veil of the "hidden abode of production."⁸⁶

If Wallerstein's approach is so promising, why then have historical sociologists not developed a research agenda around nature-society relations? Of course, any good answer to this question demands a long essay of its own. Here I would like to suggest but one part of a good answer. The great shortcoming of *The Modern World-System*, in terms of an environmental history agenda, is its essentially agrarian geographical conception of capitalism in *The Modern World-System*. Recall the volume's subtitle: "Capitalist Agriculture and the Origins of the European World-Economy...." Arguing not just against national developmentalism, but also against urban-centered approaches, Wallerstein contends that the real action was in the countryside: "The emergence on an industrial sector was important, but what made this possible was the transformation of agricultural activity from feudal to capitalist forms."⁸⁷ This emphasis on agrarian capitalism is for the most part right on target. Unless agriculture could be drawn into the orbit of capital accumulation and subjected to its competitive pressures, capitalism could not develop, much less get started.

Before long, however, the agrarian approach becomes self-limiting. Modern environmental history may be summarized in terms of unequal flows: from periphery to core, from colonized to colonizer, but perhaps above all, from countryside to the town. It is this socio-ecological antagonism between town and country that leads me to

think that *The Modern World-System's* ecohistorical promise might be extended most effectively by jettisoning the agrarian capitalism perspective. In its place, we might consider an alternative spatial conception, whereby capitalism is constituted by an evolving town-country division of labor at multiple scales – within regions, states, and the world-economy. Where to begin? The best starting point for formulating such an alternative geography may be found in Marx and Engels's conception of the town-country division of labor and its relation to capitalism's specific means of distilling socio-ecological wealth: "value."

Marx and Engels on value, ecology, and the town-country divide

From Marx's standpoint, *value* is specific to capitalism. Contrary to Marx's ecological critics,⁸⁸ capitalism's historically-specific value-form is something quite different from what is "valuable." Marx does not deny that nature does useful work, only that (from the perspective of capital) its productions do not directly enter into capitalism's particular crystallization of wealth, wherein all sources of wealth must be dissolved into the money form.⁸⁹ Far from an endorsement of capital's value form, Marx's conception is a radical critique. Indeed, the accumulation of value, by extinguishing "the natural and social characteristics" of human and extra-human nature,⁹⁰ stands in stark contradiction to "the original sources of all wealth – the soil and the worker."⁹¹ What is so striking about Marx's now famous critique of capital's tendencies to degrade land and labor is the refusal to separate the two. Capital does not exploit land *and* labor so much as it exploits the land *through* labor. It could hardly be otherwise, given the nature of capital as value in motion, whose very lifeblood is labor abstracted from its socio-ecological specificities.

Marx's value analysis is so ecologically compelling because it illuminates the contradiction between the accumulation of value as abstract social labor (its social form) and the accumulation of value as material process (its spatial form). Money emerges as the general equivalent of value, mediating the contradiction between value's "social generality" and its "material particularity" – *between the abstraction of social labor and the specificities of the external environment and the concrete labors that work it up*. Money "solves" (however temporarily) this contradiction by "abstracting from the qualitative differentiation of useful labor as conditioned by the material diversity of human and extra-human nature – the true sources of wealth."⁹²

Abstracting from socio-ecological particularities, monetary capital accumulation therefore permits, indeed *compels*, a radical simplification of nature. Where environmental historians, such as Worster and Cronon,⁹³ account for such simplification in terms of the circulation of commodities and monetary capital divorced from the production of value – an essentially Braudelien perspective⁹⁴ – Marx’s approach orients us toward the relation between place-specific commodity production and the accumulation of capital within much broader arenas. On the one hand, the endless accumulation of capital hinges on rising productivity. This entails increased control in various forms that tend generally toward the reduction of concrete labors, and therefore all manner of ecological specificities (of which labor is but one), to an “interchangeable part.”⁹⁵ On the other hand, money itself acts to dissolve ecological specificities by reinforcing tendencies embedded in the production process. “[P]rices attach to particular things and presuppose exchangeable entities with respect to which private property rights can be established or inferred,” argues David Harvey. “This means that we conceive of entities as if they can be taken out of any ecosystem of which they are a part. We presume to value the fish, for example, independently of the water in which they swim.”⁹⁶ Taking together these two moments, we can see that it is not only landscapes and non-human organisms that suffer the contradictions of value.

Among the ways that capitalism resolves the contradiction between the monetary and material moments of accumulation over the long-run is the production of new and extended configurations of town and country. The rising exploitation of the laborer is predicated on the widening and deepening of the town-country division of labor – in large part through primitive accumulation – that widens and deepens the reserve army of labor. The expanded reproduction of the town-country division, in turn, extends and intensifies the profound rupture in the nutrient cycling between the country and the city. This is the “metabolic rift,” or what Marx called the “irreparable rift in the interdependent process of social metabolism, a metabolism prescribed by the natural laws of life itself.”⁹⁷ While the rural-urban dialectic is the geographical expression of value accumulation, the metabolic rift is its ecological expression.

I have laid out only the barest outlines of a theoretical framework here, in the interest of establishing a guiding thread for historical investigation rather than a more formal model. My intent is to incorporate

Wallerstein's ecohistorical approach into Marx and Engels' ecological critique of capitalism in the interests of opening up a series of questions concerning the relation between ecology and the rise of capitalism. (These we explore below.) Above all, this approach brings human beings, through the labor process, into environmental history. From this perspective, capital transforms nature only through another force of nature – human labor power.⁹⁸ Not only do capital's transformations of landscapes variously constrain and enable accumulation in various times and places; its exploitation and consequent degradation of laborers and the labor process incorporate bodies into "accumulation strategies,"⁹⁹ at once undermining the biological conditions of social reproduction and generating potentially explosive class contradictions. As we see below, this kind of "dual" environmental history, highlighting capital's mutually relational transformation of landscapes and human bodies (external and internal nature), finds its origins in the transition to capitalism.

**Silver, sugar, and the origins of the modern world-economy:
The political ecology of European expansion, 1450–1640**

Let us return to the situation in Europe around 1400. The crisis of the "long" fourteenth century (ca. 1290–1450) strengthened the western European peasantry and weakened the states, the seigneurs, and the city-state capitalists.¹⁰⁰ Feudal relations were severely weakened in western Europe, and try as they might, the ruling classes could not reimpose the status quo *ante*. What was to be done? Europe's ruling strata had two basic options. One was an internal fix. The states, seigneurs, and merchants might cooperate in renewed efforts to squeeze the peasantry, and they might continue to wage war against their territorial rivals. And while these efforts did continue, they failed to generate new conditions for sustained economic expansion. The western European peasantry was too strong, and the embryonic interstate system too well-balanced. Alternatively, Europe's ruling strata could seek an external fix. In a situation that could have easily led (and did in fact lead) to "ruinous" conflict among the seigneurs and between the landlords and peasants, "the only solution that would extract western Europe from decimation and stagnation would be one that would expand the economic pie to be shared, a solution which required, given the technology of the time, *an expansion of the land area and population base to exploit.*"¹⁰¹

Geographical expansion resolved the feudal crisis – whose most dramatic expression was a precipitous drop in seigneurial revenues – by expanding the economic surplus, without a direct *and above all costly* confrontation with the peasantry, or otherwise requiring the ruling strata to share the bigger pie with its class enemies. As we have seen, one seigneurial response was to convert arable land to pasturage, but this met with some measure of success only in a few regions, such as Castile and England.

Far more effective was the geographical expansion. In Africa and the Indian Ocean, European expansion assumed a decidedly mercantile form. This “trading post” imperialism was enormously lucrative but essentially redistributive rather than transformative.¹⁰² It did not challenge the overwhelming tributary political economy of Afro-Eurasia’s land-based empires. Not so with European expansion in the Americas, whose importance loomed so large because it incorporated vast new agrarian zones into the emergent pan-European world-economy. Creating new agrarian spaces for commodity production outside the peasantry’s western European stronghold encouraged Europe’s beleaguered ruling strata to reshape the town-country division of labor in ways that favored capitalist development. Above all through the agency of the sugar plantation and the massive silver mining enterprises of Potosi and Zacatecas, early capitalism spearheaded the generalization of commodity production through overseas expansion, the fruits of which fueled capital accumulation in Europe’s leading cities. In turn, this accumulation made possible the extension of capitalist town-country relations and the deepening of commodity relations in the European countryside.

Silver’s greatest significance lay in helping to consolidate a new trans-Atlantic division of labor between town and country. The impact of American bullion on the rise of the West remains hotly debated. Still, it is difficult to argue that the flow of silver from the New World did not shape the era of transition in important ways. American bullion more than tripled Europe’s reserves between 1503 and 1660, and increased the total stock of silver by a stunning 50 percent.¹⁰³ Besides its profoundly destructive environmental impacts at the point of production (about which more presently), American bullion had two major effects on the socio-spatial division of labor of lasting importance, precisely because the long sixteenth century was an era of transition in which the final outcome – capitalism? feudalism? an agrarian world-empire? – was still in question.

In the first place, American silver monetized the European world-economy sufficiently that the new peripheries in eastern Europe and the New World could not easily withdraw into regional autarchy. In Poland, “the influx of precious metal . . . caused the price of agricultural products to soar” relative to the rest of central and eastern Europe.¹⁰⁴ While this might have benefited Eastern landlords, Western (especially German and Dutch) access to bullion flows and mastery of credit mechanisms helped create an uneven division of labor.¹⁰⁵ The crowning achievement of this Western strategy of uneven development was a “system of international debt peonage” that not only subordinated Polish landlords to the world market,¹⁰⁶ but gave these landlords some incentive to stay in the game. Any significant demonetization of the world-economy would likely have removed, or at any rate weakened, that incentive. (We can say the same about American planters.) Sixteenth-century inequalities between western and eastern Europe were still quite small. If delinking was increasingly unlikely, it was not inconceivable. One needed only to look farther east if there was any doubt that silver’s gravitational pull had its limits, for Russia remained outside this emergent capitalist world-economy until the age of Peter the Great.

When viewed from the perspective of the emergent “core,” the West’s strategy of uneven development enabled by American bullion was, if anything, more significant. It may be objected that the international grain trade – leaving aside the pressing question of what precisely was “international” and what was “local” in this tumultuous era – was not so important because it fed only 1–2 percent of Europe’s population in the sixteenth century.¹⁰⁷ Is that a lot? Consider that only one out of ten Europeans, at most, lived in cities. (And this includes mostly cities of only regional importance.) Which cities were the major grain importers? Antwerp, Amsterdam, Lisbon, Genoa, and so forth. So what we have is the Baltic grain trade providing a significant share of the nutritional needs of urbanites in those very places where capital was being rapidly accumulated. Baltic grain gave capitalists a hedge against local famine that, along with ensuing food riots in these major cities, could very well have brought to an end the original accumulation of capital.¹⁰⁸ American bullion at once served to lock the peripheral monocultural regimes – in eastern Europe (wheat), the Atlantic islands (sugar), the Americas (silver, sugar) – into the new division of labor, *and* ensured the stability of the major urban centers through which virtually all of the world-economy’s money capital flowed. (Then as now.) From this vantage point, we can see the

creation of a new and deeply antagonistic relation between the city and the country – and also mutually reinforcing divisions *within* the countryside. Poland, for example, was locked into a low value-added agricultural sector (grain) that allowed the Dutch to concentrate on high-value added agriculture such as garden crops and dairy.¹⁰⁹ (Not to mention the Low Countries' concentration of high-value added urban activities such as transport, shipbuilding, and finance.)

If American silver was a means of consolidating emergent global inequalities, the sugar plantation was perhaps the chief means of pioneering them outside Europe. Around sugar, first in the Atlantic islands and later in Brazil and the Caribbean, would develop a “plantation complex,”¹¹⁰ whose great innovation was to combine a new means of organizing labor (modern slavery) with a new means of organizing the land (monoculture). Far from accidental, the modern plantation's combination of a brutal labor regime with an ecologically destructive agricultural regime reflected the logic of the new capitalist system. Slavery and monoculture were not somehow incidental to each other. Quite the contrary, they were two sides of the same (world-historical) coin.

Silver and sugar not only contributed to the economic recovery from the long fourteenth-century crisis. These commodity frontiers signaled a rupture with the feudal mode of environmental transformation.¹¹¹ Feudalism, it will be recalled, degraded the environment in significant ways. Although it was primarily a system of production for use, which would seem to favor sustainable development, the lord-peasant relation limited the possibilities for reinvestment in the land. As a consequence, European feudalism tended to exhaust the soil from which it derived revenues.¹¹² The feudal system's best response to this socio-ecological contradiction was an anemic spatial fix that took the form of internal and external colonization, such as land reclamation in the Low Countries, or colonial expansion in eastern Europe. Capitalism, however, was an entirely different animal. Where earlier ecological crises had been local, capitalism globalized them. And it did so at a pace that outstripped all previously existing historical systems.

At the root of this ecohistorical difference between capitalism and feudalism is the role of commodity production in the two systems. To be sure, there was commodity production under feudalism, and there were important antecedents of the modern plantation system in the medieval Mediterranean.¹¹³ But however *widespread* this commodity

production may have been, there was no ineluctable tendency toward its *generalization*. Why? Because a society organized around the progressive generalization of commodity production undermines relations of domination based on tribute. All things being equal, social strata that benefit from this system are likely to oppose any change that might favor generalized commodity production. But as we have seen all things were not equal. The crisis of feudalism led to a convergence of interest among Europe's ruling strata in favor of a significant (and ultimately revolutionary) expansion of commodity production, most dramatically in the New World.

Now commodity production may be generalized in two ways. Goods and services may be transformed within an established zone of production. Alternatively, the zone of production itself may be extended, allowing the commodification of goods and services previously unknown or available only through trade with external areas. Given the social power of the western European peasantry – which opposed not only a second serfdom but also unrestricted commercialization, with its promise of dispossession and pauperization¹¹⁴ – geographical expansion became the preferred option. This generalization of commodity production through geographical expansion entailed two major kinds of ecological transformation: the degradation of the soil, and the degradation of the worker.

These transformations were especially destructive because they tended to effect two major kinds of change detrimental to human and extra-human nature alike. In the first instance, capital sought to simplify land and labor radically through monocultures and new specialized labor processes that sought to transform the worker into “a mere fragment of his own body” (Marx, 1977: 482). The simplification of land and labor was accompanied by unremitting pressure to increase the productivity of the increasingly simplified land and labor. Both land and labor were subjected to the “speed-up.” Capitalism is therefore doubly antagonistic to ecological sustainability, conceived as the health of the worker and the land together. The consequences of this speed-up were to set in motion all manner of transformations in the technical and social divisions of labor that would give rise to a new and progressively antagonistic town-country dialectic. Thus these were local transformations in one sense, but profoundly global in another. We explore here this dual environmental history of the worker and the soil, with special reference to the two great commodity frontiers of early capitalism, silver and sugar.

The silver mining frontier

Large-scale mining was not an invention of the sixteenth century. But if mining dates back to antiquity, its revival in the 1450s embodied and enabled broader changes in Europe's political economy. Metallurgical production of all sorts rose dramatically, particularly war-driven copper and iron output. But silver loomed especially large in a European trading network that "desperately needed sound money."¹¹⁵ The annual output of Central Europe's great silver mining centers expanded five-fold between 1460 and 1530, an astounding level not exceeded until the nineteenth century.¹¹⁶

Mining had always posed serious ecological problems. In ancient Greece, silver mining caused widespread deforestation and soil erosion.¹¹⁷ Europe's fifteenth-century silver boom bore a strong resemblance to these earlier episodes, but its articulation with European expansion made a crucial difference. The rapid geographical expansion effected by Europe's overseas empires meant that mining's socio-ecological contradictions could now be attenuated – and extended – by an early form of "globalization."

These contradictions were evident from the beginning of the mid-fifteenth-century expansion. Even at this early date, central Europe's gigantic ironworks "filled [the air] with such a stench and smoke as to trouble travelers as well as inhabitants."¹¹⁸ Mining wastes poisoned streams and aquatic life.¹¹⁹ More serious, at least from the mine-owners' point-of-view, was fuel scarcity. The smelters consumed an enormous volume of wood in the form of charcoal. A pound of pig iron – a crude product that often required subsequent refining – took somewhere around fifteen pounds of charcoal, reduced from about 75 pounds of wood.¹²⁰

Predictably, the mining expansion devoured central Europe's forests. For silver miners especially, fuel costs moved steadily upward in the face of rising competition from iron producers for access to thinning forests. Charcoal was by far the largest item in the budget of any smelter, sometimes as high as 70 percent of operating costs.¹²¹ Technological innovations only made matters worse. Introduced in Germany and spreading to England by 1500, new blast furnaces in the iron sector "allowed much greater quantities of metal to be produced in a shorter period of time" but were "inordinately extravagant of fuel at a time when western European forests were severely depleted."¹²² Fuel de-

mands intensified still further with declining ore quality. The rich veins tapped, tin yields declined by nearly half and silver yields by more than 90 percent over the course of the fifteenth century.¹²³ By the sixteenth century, there was “a general deforestation in Europe, which surpassed that of the thirteenth.”¹²⁴

Political factors too drove rising costs. By the later fifteenth century, territorial states began to actively regulate forest access for their own interests, further restricting fuel supply.¹²⁵ At the same time, peasants resisted these efforts to enclose the forest commons. This was a major issue in the German peasant war of 1525, and figured prominently in peasant struggles throughout the long sixteenth century. Nor were forest enclosures the only source of social unrest linked to the emergent mining complex that concentrated large numbers of potentially restive mineworkers.¹²⁶ Together, political pressures from above and below reinforced fuel scarcity, depressing mining profits further. Thus, there were a number of good reasons for all types of mining to move elsewhere:

Europe, because of her very expansion, was acting as if she had decided to delegate the trouble of handling of the mining and metallurgy industries to dependent regions on her periphery. In the heart of Europe, not only were falling yields limiting profits, but the “fiery furnaces” were destroying forestland, and the price of wood and coal was becoming prohibitive, so that the blast furnaces could only operate part of the time, thus immobilizing fixed capital to no purpose. Meanwhile wages were going up. Small wonder then that the European economy as a whole applied to Sweden for iron and copper; to Norway for copper; before long to distant Russia for iron; to America for gold and silver.¹²⁷

From this standpoint, the emergence of the European world-economy and global extension of extractive industries appear dialectically bound. The relocation of silver mining to the New World offered a near-perfect combination of relatively favorable ecological and social conditions: fabulously rich ore deposits and accessible sources of labor power. If Europe’s mining complex faced formidable obstacles at home, in the New World it could play a crucial role in fundamentally reshaping the hemisphere’s socio-ecological order.¹²⁸ By 1600, Europe’s silver production amounted to just 10 percent of the American gold and silver arriving in Seville, and this was only a portion (albeit a large one) of New World bullion exports.¹²⁹

At the core of this hemispheric reconstruction was city-building, the linchpin of Spain’s colonial strategy. This approach, “the direct oppo-

site of the British gradualistic model, permitted Spain to conquer and control an entire continent in a few years with a very small occupying force.” The Spanish colonial city was the vanguard of imperial advance. “From it the Spaniards moved out to a hostile environment to conquer, control, and indoctrinate the surrounding populations. Conquerors lived, by and large, in the city, while the conquered remained in the countryside.”¹³⁰

On the mining frontier, this “thoroughly exploitative”¹³¹ logic was carried to an extreme. At once dominant and dominated, mining boomtowns ruled over the surrounding countryside, even as they were subordinated to broader imperial and economic structures. They were the organizing centers not only of underdevelopment in the economic sense, but of a profoundly unequal ecological exchange between American peripheries and European cores, enabled by a new, multi-layered and globalizing town-country antagonism. The mining frontier thereby created an increasingly serious rift in the metabolism between the country and the city, within Latin American regions and at the scale of the world-economy. Nutrients flowed from country to city in the New World, and thence from urban centers in the periphery to the core. The consequence was a pattern of “*sequential overexploitation*,”¹³² whereby the exhaustion of local ecological wealth (including local sources of labor power) necessitates the geographical expansion of commodity relations, either through the progressive extension of city-hinterland relations within regions or the outright relocation of production.

Nowhere did the socio-ecological contradictions of the mining frontier appear more starkly than in Potosi, located in the Viceroyalty of Peru (present-day Bolivia). The New World accounted for 74 percent of the world’s silver production in the sixteenth century.¹³³ By far the largest producer, Potosi’s output dwarfed that of Zacatecas (Mexico) by a factor of seven.¹³⁴ Almost overnight, Potosi emerged as one of the European world-economy’s largest cities – with 120,000 in 1573, it was bigger than Madrid, Rome, or Paris.¹³⁵ Together with the mercury mines of nearby Huancavelica,¹³⁶ Potosi’s silver complex pioneered a rapid expansion of commodity production throughout the Viceroyalty of Peru and the nascent world capitalist system, with profound implications for the health of land and labor alike.

Potosi’s dramatic ascent owed as much to Europe’s expansionary political economy as it did to geology. In the quarter-century following

the discovery of silver (1545), the path from rock to pure silver was circuitous indeed. In this era, mining remained largely under Indian control. Indians mined silver ore, much of which found its way into Spanish hands as tribute. These tributary payments were then sold back to the Indians, who smelted the ore in thousands of dispersed *guayras*, small wind-ovens specially designed for the high altitude. Subsequently, the Spaniards acquired the pure silver through the market, where their purchasing power was augmented by their control of the highly lucrative coca leaf trade.¹³⁷ Coca, it seems, was the opium of the sixteenth century.

This system worked so long as ores remained rich. As ore quality declined, more and more fuel was necessary to extract less and less silver. By the 1560s smelting was no longer an effective – that is to say profitable – means of extracting silver.¹³⁸ Fuel costs began to rise, and silver output fell. (The region’s silver production dropped by nearly two-thirds between 1546 and 1571.¹³⁹) Mine work became more arduous and less remunerative for Indian workers, who increasingly decided that the game was not worth the candle. Thus did “Spanish mine owners [find] themselves confronted by a labor shortage that had very little to do with the number of Indians living in their midst.” By 1561, there were 20,000 Indians living in Potosi, but just 300 working the mines, 94 percent fewer than a decade earlier.¹⁴⁰ “In short, the pillage/conquest economy established after 1532 had reached its limit.”¹⁴¹

Potosi’s socio-ecological crisis did not go unnoticed from above. Spain’s imperial ambitions fed on American silver. “[I]t was the swelling flow of New World silver that made Philip [II] think he could conduct war both in the Mediterranean against the Turks and in the north against the Dutch.”¹⁴² The contraction of silver production was a very serious matter indeed, all the more so as it was followed by: 1) “an enormous increase” in military outlays after 1566; and 2) an increasingly severe fiscal crisis within Castile, where Philip II tripled taxes and thrice declared “bankruptcy” – in reality converting short-term into long-term debt – between 1557 and 1577.¹⁴³ As if to go from bad to worse, Philip’s financial woes were underpinned by an impending agro-ecological crisis that would only deepen in the closing decades of the sixteenth century.¹⁴⁴ It was in this context that the Crown convened a “special junta” in 1568 to address the emerging crisis, empowering a new Viceroy – Francisco de Toledo – to implement a sweeping reorganization of the Peruvian mining frontier.¹⁴⁵

Toledo's challenge? Find a cost-effective solution to the problem of declining silver output. Potosi's revival depended upon two decisive innovations: 1) the replacement of smelting with an amalgamation process that used mercury to extract silver from the ore; and 2) the large-scale replacement of voluntary with forced labor through a system of rotating forced labor drafts, called the *mita*. The first presupposed the second. The perfection of an amalgamation process adapted to Andean conditions preceded by just a year Toledo's proclamation of a geographically expansive *mita* in 1572. Mercury amalgamation made possible the profitable extraction of silver from low-grade ores, but it demanded a huge and tractable labor supply. Thus amalgamation and the *mita* were at the core of a series of socio-ecological transformations that were profoundly implicated in the commodification of land and labor throughout the region and its deepening articulation with a globalizing capitalist system.

This era of accelerated social and environmental transformation unfolded at multiple geographical scales. At the point of production, control passed from Indian to European hands. Spanish mine owners (*azogueros*) were in the midst of "evolv[ing] from low-investment, low-risk [entrepreneurs] into industrial businessmen."¹⁴⁶ Gone were the thousands of small wind-ovens. In their place were huge stone tanks, capable of holding 5,000 lbs of crushed ore.¹⁴⁷ The ore itself was crushed in stamping mills (*ingenios*) powered by a massive hydraulic infrastructure. Some thirty dams stored water accumulated during the brief and torrential wet season, driving 140 *ingenios*. This amounted to "the greatest single concentration of hydraulic mill technology anywhere" in the European world-economy, and played an important role in Potosi's ascent.¹⁴⁸ Silver production skyrocketed nearly 600 percent between 1575 and 1590.¹⁴⁹ The ambitious reshaping of the region's waterscapes generated ecological contradictions that helped to seal Potosi's fate. "Potosi was [consistently] plagued by disastrous floods,"¹⁵⁰ which may have been intensified by the forest clearance accompanying Potosi's renaissance. The collapse of the principal reservoir dam in 1626 killed several hundred and destroyed many *ingenios*, adding to Potosi's cumulative woes on the eve of the seventeenth-century crisis. From this disaster, "[t]he *ingenios* of Potosi never fully recovered."¹⁵¹

Our environmental history of the *ingenios* includes bodies as well as landscapes. For the workers who crushed the ore, conditions were perhaps even more lethal than in the mines, at least over the long

term. Inhaling dust, these workers began to suffer from silicosis, rendering them vulnerable to a wide range of respiratory diseases.¹⁵² “Apart from the harsh working conditions, Indians also became ill, some terminally, as a result [of the inhospitable climate].”¹⁵³ Nor could it have helped matters that the standard work shift was 12 hours, day and night, giving way to round-the-clock shifts during the wet season, “when advantage had to be taken of every hour of adequate water flow” to power the *ingenios*.¹⁵⁴ Although not immediately evident, this kind of shift work may be a form of ecological degradation in itself, rendering workers more vulnerable to disease and disability. “Shift work often goes against the rhythms governing many bodily functions.... It has [a negative] impact on the metabolism (the bodily processing) of various chemicals and toxins to which individuals are exposed in the course of their work.”¹⁵⁵

Mercury amalgamation, relatively speaking, was a “cold” rather than “hot” technology.¹⁵⁶ But this distinction takes us only so far. Amalgamation certainly consumed far less fuel than smelting. Yet, there was no technological fix to the new regime’s ecological contradictions. The quantum leap in the scale of production in the later sixteenth century appears to have generated greater, not less, pressure on the surrounding forests. In the first place, the extraction of mercury itself demanded a considerable volume of charcoal, resulting in deforestation around the mercury mines at Almaden (Spain) and Huancavelica (Peru).¹⁵⁷ Moreover, the mercury-silver amalgam required further heating to get at the pure silver. “At night six thousand fires burned on the slopes of the Cerro.... Because of the smoke from the ovens there were no pastures or crops for a radius of twenty miles around Potosi and the fumes attacked men’s bodies no less relentlessly.”¹⁵⁸ An early seventeenth-century source reports one-thousand Indians bringing firewood to Potosi – and that many again transporting wood for other purposes – with another thousand transporting and making charcoal (compared to 4,600 working directly in the mines).¹⁵⁹ By the time of Potosi’s zenith in 1600, “the growing scarcity and cost of fuel” caused refiners to stop heating the stone tanks containing crushed ore and mercury.¹⁶⁰ The surrounding area was quickly stripped of trees, and timber for stamp mills was sometimes trucked in from as far as 200 miles away.¹⁶¹ Transport was typically by mule and llama, and once-thick forests became pastures for these beasts of burden.¹⁶² (Some 30,000–40,000 llamas accompanied the annual labor migrations to Potosi.¹⁶³) Above and beyond the production system, the fuel demands of such a large city in such a harsh climate must have been immense.¹⁶⁴

Deforestation weighed particularly heavily on highly vulnerable mountain ecosystems that suffer from high rates of soil erosion and enjoy only a “fragile stability, easily upset by unintentional human action.”¹⁶⁵ By the mid-seventeenth century, it was already apparent that mining had exacted a huge toll on the region’s forests. A contemporary observer commented that:

Even today there is no sign the mt. of Potosi had ever had a forest, when it was first discovered it was fully covered of trees.... Today, not even weeds grow on the mt., not even in the most fertile soils where trees could have grown. The barrenness is most alarming because the mt. is now merely a conglomerate of loose gravel with little or no fertile land, pockmarked with sterile mineralized outcroppings.¹⁶⁶

Nor was the Potosi silver frontier exceptional in this regard. The sparsely wooded territory around the mining centers in the arid central Mexican plateau was quickly stripped of trees. Thereafter, “timber then had to be brought in at high cost over great distances.”¹⁶⁷ In Zacatecas, where silver mining commenced in 1546, “it took scarcely more than 40 years to destroy the forests over a radius of almost 50 kilometres round the mining and smelting district.”¹⁶⁸ West central Mexico’s mining centers, Taxco and Sultepec, fared no better. “Today, areas near those mines ... are covered by shrubs and xerophytic plants or worse, with little vegetation at all.”¹⁶⁹ In 1550, New Spain’s Viceroy Antonio de Mendoza wrote to his successor: “In just a few years a large area of forest has been destroyed [near the mines], and it appears that the wood supply will be depleted sooner than the ore.”¹⁷⁰ The introduction of mercury amalgamation in the 1550s reduced some pressure on local forests.¹⁷¹ But even here, relief was decidedly limited. Mercury was “the most expensive item in ... colonial mining.”¹⁷² Mexico’s silver frontier received the bulk of its mercury from Spain. But supply was inconsistent and transport costs high.¹⁷³ Smelting therefore remained an attractive option as long as forests were accessible and ores remained rich. In the later seventeenth century and into the next, half the silver at Zacatecas and all of it at nearby Sombrerete derived from smelting rather than amalgamation.¹⁷⁴ The upshot was that “[t]he problem of vegetation depletion around mines ... continued through the colonial period.”¹⁷⁵

Ecological contradictions above ground were matched by those underground. The success of the new system proved the curse of the new working class, the “forced wage laborers” known as *mitayos*.¹⁷⁶ The course of events in Potosi captures what seems to be the basic socio-

ecological pattern of early modern commodity frontiers. (The resemblance to the sugar frontier, as we see below, is striking.) In the early stages, high yield ores translate into high wages and decent working conditions. But sooner or later ore quality declines. When this happens, profitability begins to hinge more and more on two things: 1) rising capital intensity, manifest not only in surface infrastructures but also deeper mines; and 2) securing cheap labor power. Drawing workers either from outside the commodity economy, or only loosely articulated with it, mine owners found themselves in a favorable position not only to enjoy the fruits of cheap labor but also to exploit them with little regard to their health.¹⁷⁷ In itself, the death and bodily damage suffered by Indian mineworkers, much like slave mortality in the Middle Passage, posed no real threat to profitability in the sixteenth-century world-economy. In certain respects, the “brutal relationship” of mitayo and colonial entrepreneur was particularly exploitative and dangerous.¹⁷⁸ In contrast to slavery, the exploitation of the mitayo “did not place any investment at risk.... Immediate profitability was the overriding consideration of the entrepreneur in his relation with the forced laborers.”¹⁷⁹ This problem was reinforced further as the practice of hiring out mitayos increased in the later sixteenth century. As we see below, such overexploitation represented not only a shameful legacy of early European expansion, but also favored the reconstitution of the region’s division of labor in a capitalist direction.

Potosi’s renaissance was driven initially by the exploitation of tailings, ore that had previously resisted the smelters. But these were exhausted by the end of the 1570s. The solution? Dig deeper. A rising proportion of *mitayos* was put to work in the increasingly dangerous mines. “As the mines plunged deeper into the cerro, the work grew harder and accidents became more common. Mitayos were buried in cave-ins, suffered broken limbs in falls, and succumbed to respiratory diseases.”¹⁸⁰ These were part and parcel of the labor control problems that emerged apace with the mines’ increasing scale and depth. Mineowners increasingly disregarded colonial prohibitions and imposed fixed quotas, dramatically extending the working day. In the 1570s, for instance, the colonial state forbade more than two trips a day for *apiris*, workers who carried the ore from the mine depths to the surface. By the 1580s they were carrying as many as two dozen loads of 25 kilograms upward some 300 meters. Mine shafts often flooded, forcing mitayos to work “knee-deep in water,” rendering them susceptible to disease. Rest periods – originally two weeks for each one worked – were increasingly disregarded.¹⁸¹ By the turn of the century, “the proprietors decided they were

losing time changing shifts, so they started keeping the workmen underground continuously from Monday evening to Saturday.”¹⁸² The mines, said mineowner Luis Capoché, had become a “harsh executioner of Indians, for each day it consumes and destroys them, and their lives are made misery by the fear of death.”¹⁸³ Notwithstanding this increasingly brutal labor regime, ecology proved stubbornly resistant. Yields continued to decline. By the mid-1580s, “workers were taking out only half the amount formerly produced.”¹⁸⁴

Everywhere, mine work was (and remains) extremely dangerous. But the Huancavelica mercury mine – known far and wide as the *mina de la muerte* (mine of death) – was especially lethal.¹⁸⁵ Mercury poisoning, ravaging kidneys and the central nervous system, complemented the standard occupational hazards. Here as elsewhere, workers suffered from silicosis and tuberculosis. But in Huancavelica, the mercury-laced dust amplified the problem. “Workers remained at the mines through the week and had little opportunity to wash away the contaminating dust. This prolonged their contact with the mercury and increased its absorption by their bodies.” Nor was this the end of it. Poisoned workers carried the toxins from the productive to the reproductive sphere. Returning home, they “polluted the living quarters and contaminated their wives and children.”¹⁸⁶

Huancavelica’s workers were caught up in the same inexorable logic we saw in Potosí. Between the 1570s and the 1630s, high-grade surface deposits were exhausted. The exhaustion of ores led in short order to the exhaustion of the workers, as mineowners plunged ever deeper into the earth. Declining ore yields reduced some dangers but created new ones. There was less mercury in the dust, but drilling deeper pushed ambient temperature upward. “Subterranean heat and poor ventilation within the galleries caused mercury to volatilize, converting “the atmosphere ... into a true ‘culture’ of mercury intoxication.”¹⁸⁷ The workers had gone from the frying pan into the fire. At the same moment, declining yields led the city’s mining guild to disregard systematically the colonial state’s regulations. Huancavelica’s “naturally toxic conditions” were as a result correspondingly magnified by the guild’s profit-maximizing orientation.¹⁸⁸ Small surprise then that the mercury mines became “an increasingly dangerous” place to work. “By 1600 the environment at the mines had deteriorated to such an extent that conditions for the workers were horrific.”¹⁸⁹ As many as *two-thirds* of Huancavelica’s mineworkers died from their labor in the early seventeenth century.¹⁹⁰

Nor was mercury toxicity limited to Huancavelica. As we have seen, mercury toxicity easily spread from the mines to the household. Given the constant movement of Indian laborers in and out of mining centers, Kendall W. Brown speculates on a broader regional impact:

Perhaps [the colonial exploitation of] labor at Huancavelica hampered recovery from the post-Conquest Andean demographic collapse not only due to the deaths at the mines but also because mercury poisoning made survivors less given to procreation. Mercury contamination can also diminish female fertility, a consequence that would have affected wives of mitayos living in quicksilver-producing huts or helping at the refining ovens.¹⁹¹

The poisoning of bodies was complemented by the poisoning of land and water, and through biomethylation, back to bodies. The volume of mercury “lost” in Peruvian silver production was measured not in thousands but rather *hundreds of millions* of grams – some 300 tons *annually* between 1580 and 1640.¹⁹² “One gram of mercury poured into eighty million liters of water would be cause for concern under [U.S.] human health standards for drinking water, enough to contaminate a typical mid-western lake.”¹⁹³ Sixteenth-century sources indicate that “the most moderate loss of mercury is about a pound for every mark [8 oz.] of silver refined, *a loss that can never be recovered.*”¹⁹⁴

This was an early instance of capitalism’s metabolic rift radically extended. The nutrient cycle was not only disrupted but poisoned. Dumped into the rivers,¹⁹⁵ mercury poisoned the entire food chain – the fish, the animals who fed on them, and the humans who ate them. The bioaccumulation and consequent magnification of mercury toxicity – “concentrations of mercury in predatory fish can be a *million times* higher than in the surrounding water”¹⁹⁶ – are not only highly durable over time, but highly “mobile, moving through the environment in the water and in the atmosphere, to locations quite remote [in time and space] from the mining districts.”¹⁹⁷

The contradictions that flowed from the point of production were enabled by the imperial refashioning of Latin American political ecology. The late sixteenth-century silver boom presupposed a radical recomposition of Peru’s ecological wealth and its socio-spatial division of labor in ways that favored the maximization of commodity production in Potosi, and the progressive commodification of internal and external nature (land and labor) throughout the region. All of Peru was to be at the service of Potosi.

Our attention goes first to labor recruitment. This was the colonial state's great concern, and the pivot on which the region's new town-country division of labor turned. Needless to say, the Indians were not in a hurry to work for the Spaniards. The solution was found in the *mita*, a rotating annual labor draft. Imposed in 1572, the *mita* conscripted one in seven adult males for work in the mines, textile workshops, "and any other task ... deemed worthy of the state's patrimony."¹⁹⁸ The Potosi *mita* was by far the largest and most geographically expansive. In the 1570s, the annual draft mobilized some 13,500 workers, drawn from a region that stretched some 800 miles north to south and as much as 250 miles east to west.¹⁹⁹

This large-scale mobilization of bodies was predicated on the large-scale reorganization of space. The *mita*'s immediate precondition was the Empire's reorganization of village life throughout the Andes. Beginning in 1567 and accelerating after Toledo's arrival in 1569, the colonial state initiated the "wholesale resettlement of the native population" – perhaps as many as 1.5 million people, roughly the population of contemporary Portugal – into "Spanish-style towns."²⁰⁰ Replicating on a grander scale the peasant settlements of *Reconquista* Castile, these new "agro-towns" instantiated the urban primacy of Spanish colonialism: "[The] towns, not the countrysides, controlled and directed agriculture."²⁰¹ Here indeed is an early moment of what Marx once called capitalism's "urbanisation of countryside!"²⁰²

These nucleated villages (*reducciones*) effected three major socio-ecological transformations, reinforcing the new towns' obvious advantages for tax collection and political control. In the first instance, the concentration of Indians into more densely populated encampments provided fertile epidemiological terrain for Eurasian diseases.²⁰³ Second, large-scale resettlement often entailed the removal of Indians from lands prized by Spanish colonials. Often relocated to comparatively inferior lands, the new Indian settlements were plagued by "high water table[s], problems of salination, and fog and cloud cover that effectively reduced the growing season."²⁰⁴

Third, the *reducciones* represented a serious challenge to the region's existing political ecology. Prior to European conquest, Andean settlement and landowning were based on the principle of "verticality." The core strategy involved "working as many different microenvironments as possible" to ensure self-sufficiency and safeguard community.²⁰⁵ Throughout the Andes, the close proximity of distinct regional envi-

ronments – “the coast, the piedmont, the altiplano highlands, and the tundra steppe (puna)” – encouraged highly interdependent agro-pastoral linkages.²⁰⁶ Potato cultivation in the highlands, for instance, was supported by fertilizer (guano) supplied by coastal communities, which in turn consumed highland foodstuffs.²⁰⁷ Throughout the Andes, there emerged a “synchronized [pattern of] ecological relationships between coast, piedmont, highland, and puna,” constituting “a finely calibrated system of food transfers.”²⁰⁸

The *reducciones* insisted on a new agro-ecological order corresponding to the labor demands of the silver frontier. At the center of this new order was common-field agriculture, a cultivation system that emphasizes agro-pastoral linkages, access to commons, and community regulation of landholding.²⁰⁹ Where verticality presumed exchanges across ecological zones, such that farming and herding were “distinctive, geographically nonoverlapping activities,” common-field agriculture sundered such exchanges by stressing agro-pastoral integration. From the standpoint of the colonial state, the great advantage of the common-field system was its geographically expansive character, emphasizing land as a means of maximizing the productivity of scarce labor in place of older, intensive land-use practices. The new system minimized the labor formerly allocated to supervising and guarding herds and fields, and maintained soil fertility by substituting European livestock for vertical guano transfers.²¹⁰ Its adoption was accelerated by Viceroy Toledo’s 1575 “edict mandating a plow and oxen for each Indian agglomeration.”²¹¹ This technological innovation promised an important change in Andean socio-ecology, shifting from a labor-intensive to a land-extensive approach:

Where the Indians had farmed land with a dibble, the Spaniards introduced a light plow drawn by oxen.... With this new instrument, men were probably able to farm land which they had not farmed before: the plow with a metal tip is a much better tool for loosening deep sod and breaking up the tangle of roots and rhizomes than the hoe ... [Yet,] in its net effect, the plow also upset the balance of Indian life on the land. The plow is efficient only where land is plentiful but labor is scarce. Plow agriculture does not produce as much as hoe cultivation on any given unit of land.... Also, plow agriculture means that oxen must be fed, and some land must be devoted to their care.... [E]very unit of land withdrawn from Indian agriculture meant a halving of the food supply on that land [assuming that hoe yield ratios were twice that of plow ratios], and thus a halving of the population dependent on that food supply. And when that land was planted to wheat to feed the Spanish conquerors [or non-agricultural workers in the mines] rather than the Indian inhabitants of that land, the growing imbalance between man and land was intensified.²¹²

The livestock-plow system was complemented and indeed made possible by a second moment of “ecological imperialism”: the invasion of Europeans’ favored crops, wheat and barley.²¹³ Demand for wheat was high from the earliest moments of Spanish colonization, and commercial production dates from the late 1530s.²¹⁴ “In some locales [Indians] were growing it as ... [a] food staple by the late 16th century.”²¹⁵ If the common-field system reduced labor inputs by cutting supervision costs, and the livestock-plow system effectively substituted land and animal power for human labor,²¹⁶ wheat offered a further labor-saving (but land-consuming) bonus. Relative to indigenous crops, wheat demanded little labor and enabled plow agriculture by tolerating the new animals’ grazing patterns.²¹⁷ In contemporary Europe, the chief ecological trade-off was its tendency towards low yields and soil exhaustion: wheat “devours the soil and forces it to rest regularly.”²¹⁸ It was the colonizers’ great fortune, however, that the New World’s fertile soils counteracted this tendency. Initially, wheat cultivation in Peru supported seed/yield ratios 3–6 times higher than Europe’s average, liberating still more labor from the demands of subsistence production.²¹⁹ Wheat’s ecology could not be ignored completely: the tendency towards soil exhaustion necessitated frequent fallow periods as well as livestock to restore fertility. Hence the importance of the common-field.²²⁰ American soil, however, did favor the transfer of a European agronomic complex that created surplus labor in the villages and provided a crucial subsidy for early Spanish commercial agriculture.

Achieving its “clearest expression” and most durable form in those villages most heavily burdened by the mining frontier’s labor demands, common-field agriculture responded well to the colonial state’s demand for a “reservoir of cheap labor for the mines.”²²¹ The net supply of laborers increased. But only for a time. The *reducciones* and common-field agriculture helped create a regional commodity-oriented political ecology that sustained demographic decline into the eighteenth century and thus the demise of that very labor surplus it had created.

Providing the administrative and spatial framework for the *mita*, the *reducciones* established the conditions for yet deeper transformations of land and labor. The mining frontier’s power to call forth all manner of economic linkages in the formation of a new regional division of labor cannot be reduced to simple market demand. This was no Smithian dynamic.²²² Of course, colonials established commercial agriculture in response to commercial opportunities, especially those

arising from the mining frontier. (How could it be otherwise in a region where something like half the silver produced stayed put?²²³) But this development presupposed the disrupting effects of Europe's social and biological expansion, which transformed indigenous society in ways that encouraged a significant (if still partial) turn towards commodification.

We can identify three main sources of disruption linked to the silver frontier's commercializing impulse. The first, as we have seen, was the colonial state's relocation of native communities. Of course this often amounted to outright land theft. Concentrating scattered Indian settlements, the *reducciones* opened up vast new expanses for colonial agriculture and stockraising.²²⁴ But this was only the beginning. In the half-century after 1570, the appropriation of land escalated still further. The number and size of Spanish estates increased several times, made possible largely through the state's "direct intervention ... accelerat[ing] the distribution of land to the Spanish settlers." European conceptions of private property were beginning to supplant indigenous notions of communal property.²²⁵ Colonial landholdings were useless without labor, which the state mobilized through an agricultural *mita* five times larger than New Spain's.²²⁶ By 1630, haciendas "dominated the urban and mining markets" for maize, and presumably wheat as well.²²⁷

This dual process of land clearance and land appropriation – whose greatest impetus was the mining frontier – was undoubtedly made easier by rapid depopulation owing to Eurasian disease.²²⁸ But depopulation cannot be explained solely in terms of the initial epidemiological onslaught. Among the factors driving prolonged demographic decline was the proliferation of Old World animals deliberately introduced to aid the colonial project.²²⁹ Obviously central to the development of the mining frontier,²³⁰ these livestock not only carried disease but, particularly in the case of sheep and cattle, entered into competition with the overall *system* of indigenous cultivation, dramatically undermining these societies' socio-biological reproduction.²³¹ The classic instance of this process is New Spain, where the livestock economy was also given life by the mining frontier.²³² For a number of reasons things played out differently in Peru. Among these was the initial success of the resettlement program, which not only allowed for a significant expansion of stockraising, but constituted an important wedge in expanding European land claims over time. By the late sixteenth century, a rising cattle population inflicted widespread dam-

age on Indian fields, leading peasants to move “their fields outside the range of the roaming beasts. . . . Once the peasants abandoned the land, the Spanish moved in permanently and grazed it or cleared it.”²³³

Potosi’s voracious appetite for labor, satisfied in large measure through the mita, was a third source of disruption. Knitting together the region’s pueblos in a new town-country division of labor, the mita created a favorable disease environment whose effects were felt in the “murderous epidemic.”²³⁴ This contradiction was reinforced by others. Pulling labor out of the villages, the mita undermined socio-ecological reproduction over the short- and long-run. First, the mita often withdrew labor at “crucial moments in the agricultural cycle,” further destabilizing traditional production relations in “labor-intensive agriculture.” When mitayos returned, many were too sick to return to agricultural labor or found their fields “deteriorating or unworked.”²³⁵ But many did not return. There was a long-term hemorrhaging of labor, as mitayos left permanently, many of them taking up residence in the mining camps and haciendas.²³⁶ This of course rendered the mita progressively more burdensome for those who remained, which further hastened the dissolution of the old order. Between 1581 and 1609, villages within the Potosi mita lost one-third to one-half their population, with even sharper declines in some locales.²³⁷ By the early seventeenth century, there were some 76,000 Indians – an early mining proletariat – in Potosi not bound by the mita.²³⁸

Village depopulation, the formation of a mining proletariat, and declining ore quality in Potosi combined to favor the gradual substitution of cash payments for labor service, a process that would significantly alter the relation between indigenous society and the land. By the early seventeenth century, it was becoming “clear to all concerned that the mita was little more than a heavy tax burden.”²³⁹ In 1606, silver payments satisfied some 20 percent of the mita’s obligations, a figure that would reach one-third to one-half by the 1620s.²⁴⁰ “Whatever the actual fraction of the mita that was satisfied in money, the sums involved were enormous.”²⁴¹ The indigenous political class (*kurakas*) responded by turning to commodity production. European crops such as wheat and barley were especially favored.²⁴² While some *kurakas* grew rich, more general commodity production was associated with rising indebtedness and land alienation.²⁴³ This was a development fraught with unhappy implications for indigenous society’s socio-biological reproduction:

As tribute and other community obligations increased, these lands were often sold or rented to discharge debts. Shortages of labor and land at times [of] increased extracommunal demands on Indian communities led to food shortages and even famines. These situations resulted not only in acute starvation in some cases but also in malnutrition, which increased the susceptibility of Indians to illness and disease and probably reduced the effective birthrate through maternal malnutrition during pregnancy and lactation.²⁴⁴

Taken as a whole, the mining frontier's socio-ecological contradictions generated long-term impoverishment rather than growth. The very speed with which the Potosi veins were exploited at once led to rising costs apace with declining ore yields and contributed to a global overproduction of silver – whose price fell by about one percent per annum between 1540 and 1640.²⁴⁵ This much is predicted by ecologically-informed conceptions of the mining economy.²⁴⁶ But our story here adds a new wrinkle. Earlier, we saw that the rise of Potosi was conditioned by developments within Europe, not least problems within central Europe's mining sector. In Braudel's words, Potosi was but one moment in Europe's grand movement to “delegate the trouble of handling of the mining and metallurgy industries to dependent regions on her periphery.” By the early seventeenth century, however, Potosi too would succumb to the contradictions embedded in its ascent: “the very rapidity with which the *cerro rico* had been exploited soon led to the exhaustion of its high grade ores, whereas in New Spain [Mexico] the rich middle zones of the lodes had barely been tapped.”²⁴⁷ This was “sequential overexploitation” in action: Potosi's exhaustion gave way to New Spain's ascent. The silver frontier's center of gravity had shifted. It would not be the last time.

The sugar frontier

Sugar was the original cash crop of European expansion. Like the silver mining center, the sugar frontier reflected and instantiated capitalism's tendency to accelerate environmental degradation, to intensify exploitation of labor and land (human and extra-human nature), and to globalize these exploitative and transformative production systems. But there was a crucial difference: If silver mining was indispensable to the rise of the modern world-economy as a system of capital accumulation, the sugar plantation remade the divisions of labor necessary for this early accumulation to be not only “original” but ceaseless. In contrast to the mining frontier, the plantation could

take root almost anywhere in the tropics. Its concentration and organization of labor and capital prefigured the rise of modern industry in the later eighteenth century.

The sugar frontier's economic success flowed from its novel reorganization of land and labor. Imposed on fertile tropical landscapes, modern slavery and monoculture made sugar one of the very few growth crops of early capitalism. By the same measure, the very reorganization of land and labor that ensured sugar's profitability exhausted the soil and the workers who made it possible. In essence, the land was progressively mined, until its relative exhaustion fettered profitability, whereupon capital was forced to seek out more fertile lands, that typically were found outside the established boundaries of the capitalist system. Successive "local" ecological crises became a driving force of capitalism's global expansion.

By the standards of the day, the sugar plantation was unusually capital-intensive, organizing and coordinating a highly complex labor process. In great measure, this prefigurative agro-industrial operation was mandated by the ecology of sugar cane. Because cutting, milling, and boiling must occur within 48 hours of harvest – otherwise the cane will desiccate and lose its value – sugar's ecology favored on-site "bulk reduction," which in contrast to a crop like tobacco tended to realize economies of scale.²⁴⁸ In contrast to wheat but similar to cotton, sugar also demands year-round labor, which encouraged slavery over free labor. Finally, sugar's agro-ecology, reinforced by the demands of a competitive world market, also tended to favor a highly rationalized organization of labor.²⁴⁹ During the harvest, slaves worked the sugar mills and boilers around the clock.²⁵⁰ Cultivation and processing required both skilled and unskilled labor, providing an early glimpse into the capitalist labor process, including skill reduction. "The specialization by skill and jobs, and the division of labor by age, gender, and condition into crews, shifts, and 'gangs' ... are features associated more with industry than agriculture – at least in the sixteenth century."²⁵¹ Increasingly, a new conception of time – what Thompson would call "industrial time"²⁵² – prevailed. While "dictated by the nature of the sugar cane and its processing requirements, ... [this time consciousness] permeated all phases of plantation life."²⁵³

While Europeans had grown sugar in the Mediterranean from the time of the Crusades, Portugal's incorporation of the Madeiras and Azores in the mid-fifteenth century inaugurated a new phase of world environ-

mental history. Although small, the Atlantic islands “were as important as continents.”²⁵⁴ Madeira was destined to play an especially decisive role. Over a decade before Portuguese settlers arrived on this uninhabited island, they had put ashore cows, pigs, and sheep – a strategy of ecological imperialism subsequently repeated in the Azores, the Cape Verdes, and the Caribbean. Consequently, Madeira’s ecology was transformed even before human arrival. This was not always to the settlers’ advantage. The attempted settlement of nearby Porto Santo was hampered by the accidental release of rabbits on the island in the 1420s. The rabbits devoured the island’s ground cover, leading to wind and rain erosion.²⁵⁵ For the moment, Madeira’s heavy forest cover protected the island from a similar fate.

Madeira’s forests were among the first victims of Portuguese expansion. “There was not a foot of ground that was not entirely covered with great trees,” observed a Venetian traveler in the 1450s.²⁵⁶ Resting on the twin pillars of shipbuilding and sugar production, the political ecology of Portuguese imperialism ensured rapid forest clearance. Its domestic timber supplies chronically deficient,²⁵⁷ Portugal’s emergence as a world power owed much to the exploitation of these woods. World power required a world naval and merchant fleet. And Madeira provided precisely the right kind of “old growth” timber – of “record size and quantity”²⁵⁸ – for the larger oceangoing vessels that would carry Portuguese power into the Indian Ocean.

If shipbuilding required select timbers, sugar was far less discriminating, and ultimately far more voracious in its appetite for wood fuel. Even with the most favorable soil and climate, no sugar plantation could succeed without access to nearby woodlands.²⁵⁹ Displacing the cereal agriculture of the early settlers, Genoese and Flemish capital financed the new sugar plantations, whose annual output increased from about 80 to 1,300 tons between 1456 and 1494.²⁶⁰ By the latter date, some 60,000 tons of wood each year were consumed in the island’s boiling-houses.²⁶¹ This does not include wood for heating, construction, building casks, or sawmilling planks for export to Lisbon’s shipyards. Sixty-thousand tons, while small in relation to Europe’s overall consumption, was nearly twice as much wood as Europe’s merchant shipbuilding consumed every year.²⁶² By the end of the fifteenth century, sugar importers began to build refineries in northern Europe, because nearby fuel supplies were rather more plentiful than in the islands.²⁶³ Sugar sealed the forests’ fate.

Madeira's sugar revolution was above all the work of human labor. The destruction of the island's forests irrevocably altered its hydrology. Perennial streams went dry, requiring new systems for mobilizing water if sugar was to be grown.²⁶⁴ The ensuing construction of massive irrigation works was as global as it was transformative. Technical expertise and financing were supplied by the Genoese; Portugal provided settlers; and African slaves performed most of the labor. The sugar frontier's huge appetite for labor exacted a high price. "Much of the land was too steep for normal practices of cultivation and had to be terraced. Most back-breaking of all the tasks, *and the most dangerous*, was the creation of a vast and complicated irrigation system to bring water from the windy and sodden uplands to the cultivated fields far below."²⁶⁵ Once the sugar was harvested, the boiling houses became a "sweet inferno." The men who watched over the boiling sugar – often 30 hours at a stretch – "are so exhausted, covered with smoke, soot, dirt and clay that they resemble demons."²⁶⁶

Madeira became the world-economy's largest sugar producer by the late fifteenth century, its ascent propelled by an expanding world sugar market, the consolidation of large landholdings thanks to Genoese financing, and sufficient labor power provided by the slave trade.²⁶⁷ By the 1490s, however, the world sugar market was glutted. Global conditions overlaid local contradictions. Overproduction coincided with increasing soil erosion and exhaustion. But not only was the soil exhausted. So were the slaves. By the end of the century, some 2,000 slaves worked the island's sugar plantations. But slave mortality was high. Five to ten percent of the slave population died each a year²⁶⁸ – a figure that refers to the established plantation, not to the exhausting labor of clearing forests. As long as profits held, this was not a major concern. Slaves typically lived long enough to recoup the original cost, and then some.²⁶⁹ This was all that mattered. Thus, when brought to the modern plantation, at first in Madeira and later in the New World, African slaves not only supplied the labor power necessary to degrade local ecosystems, but in the process of capitalist exploitation the slaves themselves experienced the most thoroughgoing form of ecological degradation – death.

This dual crisis – of the soil and the worker – undercut productivity and led directly to the relocation of sugar production from the Atlantic islands to Brazil by the mid-sixteenth century. Madeira's sugar complex, itself the product of early capitalism's globalizing tendencies as capital accumulation began to shift from the Mediterranean to the

Atlantic, had by the mid-1500s generated contradictions that only another wave of global expansion could resolve.

The sugar frontier's movement from the Atlantic islands to Brazil, and thence to the Caribbean, is a paradigm case of how early capitalism resolved crises in one region only by transferring such "contradictions to a wider sphere and giv[ing] them greater latitude."²⁷⁰ As sugar yields fell, Flemish and Italian capital – the decisive ingredient in Madeira's ascent – began to direct their attention to Brazil.²⁷¹ Among the New World's advantages was plentiful water. The hydrologic cycle was not so easily disrupted, and large-scale irrigation works were typically unnecessary. Indeed, the "discovery that sugar could be grown well in the New World without irrigation made American cane plantations the prototype of virtually" all subsequent plantation systems the world over.²⁷²

The rise of a capitalist world market created new pressures to push land and labor beyond sustainable limits. Increasingly, planters found themselves in a position where they had to "sell to survive." Intensifying competitive pressures within the sugar sector – planters were typically heavily indebted and membership in the planter class was highly unstable²⁷³ – encouraged planters to overexploit land and labor. Typically within the course of a century this undermined productivity drove the sugar frontier ever onward to virgin soil, which in turn required fresh supplies of capital and labor. A vicious circle indeed! American planters were yoked to a globalizing system of debt peonage reminiscent of early modern eastern Europe.²⁷⁴ Italian, Dutch, and British financiers, not planters, were the primary beneficiaries of the sugar frontier.²⁷⁵ These financiers' accumulation, of course, depended upon renewed primitive accumulation on a massive scale in the Americas, in this instance the incorporation of Brazil's ecological wealth into the world capitalist system. Reflecting capital's disregard for nature, the early settlers "presumed upon the inexhaustible fertility of cattle, turtles, and birds, and upon the immeasurable resources of the forests: indeed, they seem to have gone berserk in the presence of so much edible wild life and a continent covered with firewood. In time, this waste went too far."²⁷⁶

In Brazil as in the Atlantic islands earlier, the forests were laid waste. Planters believed that sugar grew best on forest soil, and in little over a century (1580–1700), occupied some 1,000 square kilometers. Forests were cleared for cultivation, and then for fuel. By 1700, "an average

210,000 tons of secondary woodland ... forest was cut each year” for the furnaces. The result: another 1,200 square kilometers of woodland permanently removed.²⁷⁷ Second only to slaves as the largest item in the mill owner’s budget, by the eighteenth century, firewood consumed some 12–21 percent of operating costs.²⁷⁸ Rising fuel costs combined with soil problems as an important contributing cause to plantation failures, beginning in the seventeenth century.²⁷⁹ At this time, a large Bahian *engenho* typically required the full-time labor of eight slaves just to gather firewood. Each slave’s *daily* quota was approximately 1,600 pounds of firewood. During the harvest season, every large *engenho* in the region consumed some 12,000–13,000 pounds of firewood on a daily basis.²⁸⁰ Reflecting the land-extensive emphasis of European expansion, one-and-one-half to two acres of forest were needed to process a single acre of sugar cane. By the end of the seventeenth century, Brazil’s sugar frontier occupied no less than 2,500 to 3,000 square kilometres (excluding cereal and livestock acreage), an area about one-third the size of Portugal. Widespread deforestation was evident in the Bahian Reconcavo by the mid-seventeenth century.²⁸¹ The region’s once-rich soils had given way to “sterile-rock, washed-out soil, eroded lands.”²⁸²

The Caribbean sugar frontier replayed this contradiction on a grander scale in the seventeenth century. Declining soil fertility, slave revolts, war, and a gold boom in the south undercut Brazil’s position as a leading sugar producer. Dutch capital and expertise moved north to Barbados.²⁸³ The geographical shift encouraged an important socio-ecological innovation. Where distinct actors in the Atlantic islands and Brazil organized processing and cultivation, the hallmark of Barbados’ famous sugar revolution was its systemic combination of the two.²⁸⁴ This development owed everything to a growing sugar market. American production tripled between 1600 and 1630.²⁸⁵ An expanding market sustained profitability and rendered the Brazilian sharecropping system – effectively a risk-minimizing strategy on the part of the millowners – less desirable for Barbados’ incipient planter class.²⁸⁶ While the holdings of Brazil’s cane farmers averaged between 15 and 25 acres, in Barbados “a couple of hundred sugar magnates” monopolized the best land and operated estates nearly ten times larger.²⁸⁷ (The scale of production would increase yet again in eighteenth-century Jamaica.²⁸⁸) The new system worked. Barbados sugar was at the center of an enormous expansion of world demand and the British market in particular. West Indies’ sugar exports to England – a third of which was reexported – jumped by about 150 percent between the

1660s and 1700, driving Brazilian sugar from northern European markets.²⁸⁹

The creation of large estates was abetted by large-scale forest clearance, the first stage in making a “virtual biological wasteland” of Barbados.²⁹⁰ This was deadly work: “there seems no doubt that [the slaves] were worked much more intensively than formerly, and even to the point of death in many instances, in the accomplishment of this task.”²⁹¹ Originally covered with “dense tropical forests,” Barbados was virtually deforested in the thirty years after initial settlement in the 1630s. By the 1660s, some fifteen years after the first sugar exports, “Barbados had less woodland than most districts of England.... [C]olonists were complaining of a timber shortage.”²⁹² These colonists even attempted to annex nearby St. Lucia, prized for its dense forests.²⁹³ Where Brazil’s cane farmers had practiced timber self-sufficiency, this was quickly rendered impossible in Barbados. By 1665, “all but the most isolated patches of forest” were gone.

Gone too was the ecological advantage of retaining forest land within and between sugar estates, which protected against soil erosion.²⁹⁴ This would become a serious problem in the later seventeenth century. “Rivers began to silt up and in some cases went completely dry, estuarine habitats were destroyed by siltation and estuarine animals disappeared; and with the loss of the dense tree cover the whole hydrology, and thus the whole climate, of the area was slowly altered, at considerable cost to both land and water species.”²⁹⁵ Erosion from nearby cane fields began to clog Bridgetown harbour in the early 1660s, after just two decades of sugar cultivation.²⁹⁶

Problems of soil erosion compounded the rising challenge of soil exhaustion. By the closing decades of the seventeenth century, Barbadian planters “complained endlessly of declining crop yields, insect and vermin plagues, drought, barren soil, and rising costs.”²⁹⁷ Between 1649 and 1690, the volume of sugar produced on one acre fell by a third, and yields on many sugar estates declined by as much as one-half.²⁹⁸ Declining soil fertility also signaled sharply falling yields for “ratoon” crops, where the cane root is left in the ground to produce a second (or even third and fourth) cane. Despite its minimal labor demands, by the eighteenth century, yields had fallen so dramatically that “no planter ratooned more than one year.”²⁹⁹ Such exhaustion played a key role in the eighteenth century shift of sugar production from Barbados to the larger islands of Jamaica and St. Domingue,

which “had sufficient land to be able to abandon overworked sugar plantations and replant on virgin soil.”³⁰⁰

The deepening crisis of the soil demanded ever-greater inputs of fertilizer and labor. The metabolic contradictions *within* the countryside were consequently sharpened as producers became increasingly specialized. The challenge of declining soil productivity was met, in part, by importing animals to supply fertilizer. This option was, however, a limited one in the smaller islands such as Barbados, and at all turns led to more deforestation for pasture, which resulted in yet more soil erosion, and yet greater demand for fertilizer. In seventeenth-century Brazil, the booming sugar sector provided the impetus to large-scale cattle ranching, where cattle were used initially as a power source for the sugar mills.³⁰¹ In Barbados by the mid-seventeenth century, fertilizer costs increased to the point where smallholders began to raise livestock not for meat or hides, but as a source of manure.³⁰² The spatially concentrated animal population – especially horses, the power source for many sugar mills – provided a favorable disease climate. In 1655–56 “a virulent epidemic almost destroyed the horse population in Barbados.” This development threw the sugar mills into crisis, and induced a shift to wind-power, possible because the island had been so thoroughly deforested.³⁰³

As soil fertility declined, more labor was required – and slaves were the most costly part of the production process.³⁰⁴ During the late seventeenth century, slaves in Barbados were put to work carrying soil that had washed to the bottom of cultivated hillsides back to the cane fields.³⁰⁵ Labor costs rose dramatically. Among the more innovative responses to the emerging crisis of the soil was a shift away from trench planting – which encouraged “massive” water and wind erosion – in favor of hole planting by the early eighteenth century.³⁰⁶ Cane-hole planting was reasonably effective but also highly costly in terms of the labor involved. This was “tedious, labor-demanding work to which planters resorted only when environmental constraints combined with market opportunities to make it a rational strategy.”³⁰⁷ Declining soil fertility and rising labor inputs were the order of the day. By 1717, an acre planted with sugar in Barbados required five times as many slaves, “and many more head of cattle and horses,” relative to the relatively more expansive (and therefore more fertile) French sugar islands.³⁰⁸ Even on much larger Jamaica, as early as 1740 Charles Lesley observed that “100 Acres of Cane require almost Double the Number of Hands they did formerly, while the land retain’d its natural

Vigour.”³⁰⁹ Over the next half-century, Barbados’ slave population increased by “about 30 percent” but sugar output declined by “more than 20 percent.”³¹⁰ It is no surprise that profitability fluctuated sharply according to soil conditions.³¹¹

The degradation of the soil not only demanded more workers. It demanded more *out of* the workers. When the planter purchased more slaves to compensate for declining yields, pressures to exploit the soil and the slaves were accordingly intensified – above and beyond the chronic pressures of indebtedness and downward price movements. Thus, there was the “terrible depreciation allowance” of slave mortality.³¹² “The sugar plantations on which over three-quarters of all Caribbean slaves worked consumed the lives of slaves almost as voraciously as the mills ground the mounds of cut cane.”³¹³ Estimates of slave mortality in the seventeenth-century West Indies sugar frontier vary, but one trend seems clear. Economic growth and slave mortality were closely linked.³¹⁴ Comparatively low mortality in the early years of settlement gave way to escalating mortality in later years. As Barbados’ sugar exports to London surged 300–400 percent in the second half of the seventeenth century, annual slave mortality – 3.5 percent in 1627–1650 – increased some 40 percent (to 4.9 percent) by 1700.³¹⁵ Might this have something to do with available land, and therefore relative soil fertility? One answer is suggested by way of comparison with Jamaica. Slave mortality in Jamaica, an island that could accommodate 25 islands the size of Barbados, was initially lower (2.8 percent) during the establishment of the plantation regime in the 1650s, and increased much less dramatically (about 25 percent) in the ensuing 75 years.³¹⁶

The sugar frontier knitted together deforestation, soil erosion, and human health in one other respect: yellow fever. This would have far-reaching implications for European imperialism in Latin America. Indigenous to tropical Africa, and transported to the New World in slave ships, yellow fever took root in the Americas as a consequence of the Caribbean sugar revolution. Receding forests undermined the bird populations that preyed on fever-carrying mosquitoes, who found the expansion of marshland at the expense of forest a favorable breeding ground. Above all, in concentrating large numbers of workers, the rapid expansion of sugar estates created an enormously favorable environment for the virus. While local populations eventually adapted, yellow fever posed serious difficulties for invading armies. British and French efforts at projecting their hegemony in the region were

continually frustrated by the virus during the eighteenth century. Overall, the epidemiological landscape produced by the sugar frontier's ecological transformations "created a new set of governing conditions for international relations in the American tropics."³¹⁷

Silver and sugar. These were central to an epochal change in nature-society relations accompanying the rise of capitalism, as world-economy and *world-ecology*. From the standpoint of the commodity frontier, early capitalism's ecological contradictions come into view. In particular, we see the emergence of capitalism's metabolic rift and its tendency toward the globalization of ecological problems. On the silver mining frontier, the rise of giant mining centers not only ensnared whole regions in its commodity-producing web but ensured that ecological wealth would flow from countryside to (mining) town, and from colonial city to imperial metropolis. At each step, nutrient cycling was disrupted as local ecologies were harnessed to Europe's territorial and capitalist ambitions. The disruptions attendant upon the incorporation of local ecosystems into the emergent capitalist world-ecology were at the heart of recurrent waves of colonial expansion. This pattern of sequential overexploitation, which we witnessed in the mining frontier's re-centering from Peru to New Spain, found its most dramatic expression in the sugar frontier.

The sugar plantation's novel contribution was an extension of the metabolic rift's underlying logic. In these successive frontier zones – stretching across the early modern Atlantic world – capital and the colonial state had free reign to impose an unfettered commodity regime. The very nature of the commodity, now embedded in a system that promoted its generalization, rendered this new regime enormously effective at dissolving nature's ecological particularities in the interests of capital accumulation. Enter capitalism's tendency toward the radical simplification of land and labor, that is to say external and internal nature. Plantation monoculture and row planting, far from mere cultural traits accompanying European expansion, were fundamental to early capitalism's most prefigurative socio-ecological order. Resting upon a labor process with low skill requirements, slavery was possible largely to the extent that the physical organization of the land itself was progressively simplified.³¹⁸ This is why monocultures and row planting went hand-in-hand with the origins of modern slavery as far back as the fifteenth century. The imperatives of commodity production ensured that simplification rather than variation was the preferred ecological norm, and that short-run profit-maximizing strategies were favored

over long-run ecological sustainability. Far from static, the metabolic rift's ecological drain was implicated in and reinforced by a globalizing logic of commodity production favoring the simplification of land and labor – a process that implied and indeed necessitated geographical expansion.

Conclusion

Whether or not we now face an imminent crisis in the biosphere's capacity to sustain human life remains an open question. One thing is certain, however. The scale and scope of environmental problems is larger than ever before in human history, and the future relation of the global economy and the biosphere is deeply uncertain. "It is impossible to know whether humankind has entered a genuine ecological crisis," J. R. McNeill concludes in his recent environmental history of the twentieth century. But there seems little question that the world-economy is headed in this direction. "Many of the ecological buffers – open land, unused water, unpolluted spaces – that helped societies weather difficult times in the past are now gone. The most difficult passages will probably ... involve shortage of clean fresh water, the myriad effects of warmer climate, and of reduced biodiversity."³¹⁹ These and other problems – whether conceptualized as crises or not – will sustain rising popular and scholarly interests in not only the contemporary dynamics, but also the historical development and origins of nature-society relations over the long run. The significant growth of world environmental history in recent years is unlikely to stop any time soon.

This article makes a sustained effort to bring nature "back in" to the world-historical perspective, and to incorporate the insights of social theory into world environmental history. I have turned, in the first place, to *The Modern World-System*, not because it is absolutely correct in every instance, but rather because Wallerstein takes seriously the proposition that nature and society are mutually relational. He does so in a way that establishes rather than elides the historical-geographical specificity of capitalist and non-capitalist socio-ecological contradictions – in sharp contrast to the dominant tendency within environmental history today. What makes this effort particularly compelling, in my view, is its attention to production. For Wallerstein, as for Marx, the degradation of the soil and the degradation of the laborer are dialectically bound. Wallerstein's breakthrough was to show, historically,

how these local-scale transformations on the one hand were determined by world-scale structures and forces and on the other were constitutive of those very same world-historical patterns. Where many within the world-historical perspective have drifted toward a standpoint that renders nature exogenous to society,³²⁰ Wallerstein illuminates the mutual determination of ecology and society, a relation mediated by human labor power – itself at once a force of nature and a force of society.

Wallerstein's chief failing, from the perspective of environmental history, is the agrarian geographical conception of capitalism. The town-country antagonism, so central to Marx and Engel's ecological critique of capitalism, remained a secondary concern in *The Modern World-System*. While it may have had some impact on the development of a historical sociology of environmental change, this weakness is easily remediable. Turning to Marx's conception of metabolism – and especially a "metabolic rift" between the country and the city – we can begin to comprehend the rural-urban dialectic as the overarching ecogeographical framework of the modern world. The cycling of nutrients and water between town and country has been progressively disrupted over the past five centuries of capitalist development, requiring successive spatial fixes, large and small. Far from exogenous to capitalism, the new town-country antagonism that took shape in the long sixteenth century was initially rooted in primitive accumulation and subsequently reproduced also through the accumulation of value, with its contradiction between the material basis of production and the monetary abstraction of socio-ecological particularities.

I am not suggesting that this is the only possible way to interpret the environmental history of the transition to capitalism. Robert Brenner, for instance, has begun to acknowledge the importance of eco-geographical factors in a recent discussion of the transition to capitalism in the Low Countries.³²¹ Yet, Brenner's regional focus seems unduly narrow. In my view, it seems rather more reasonable to acknowledge the socio-ecological remaking of the New World, and its effects on European economic development, as a significant (if not at every turn decisive) moment in the rise of capitalism. The very hallmarks of capitalism's present-day environmental degradation – especially monocultural production – were inscribed in the colonial enterprise, itself little more than a great machine designed for the transformation of ecological into monetary wealth.

If it is not the only possible approach, my sketch of the early modern sugar and silver mining commodity frontiers indicates the potential of three concepts – even the outlines of a general approach – for the study of modern world environmental history. First, the theory of metabolic rift draws our attention to the reshaping of town-country relations at multiple scales in the long sixteenth century. Second, the ecological interpretation of the antagonism between value accumulation and ecology, among other things resulting in a radical simplification of the latter, allows us to put labor into the mix of environmental history. Putting labor at the center in this way accomplishes two main things. It sheds light on the relation between place-specific production and larger socio-spatial relations, such as town and country. And it undermines dualistic conceptions of nature-society in favor of analyses that see human beings as a force of nature in themselves. Finally, my conception of the commodity frontier balances place and space in the geographical expansion of capitalism, emphasizing production as well as exchange in contrast to the alternative market-centered formulations offered by Innis and Cronon.³²² This conception of the commodity frontier deepens the world-historical interpretation of environmental history by illuminating the relation between local ecological crises and the world-economy's successive waves of restructuring and geographical expansion. The overall approach is one that suggests a potentially fruitful angle of vision from which to understand, among other things, capitalism's unsustainability at the very largest and very smallest geographical scales – how the world-economy and the laboring body are mutually constitutive of, and relational to, each other over long historical time.

Notes

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2. In contrast to the 1970s, this world-historical renaissance now pivots on East Asia and the "Rise of the West" rather than the transition to capitalism. Among others, see Giovanni Arrighi, Beverly J. Silver, et al., *Chaos and Governance in the Modern World System* (Minneapolis: University of Minnesota Press, 1999); Andre Gunder

- Frank, *ReOrient* (Berkeley: Univ. of California Press, 1998); Jack A. Goldstone, "Efflorescences and Economic Growth in World History: Rethinking the 'Rise of the West' and the Industrial Revolution," *Journal of World History* 13/2 (2002): 323–389; David Landes, *The Wealth and Poverty of Nations: Why Some Are So Rich and Some So Poor* (New York: W.W. Norton, 1998); Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton: Princeton University Press, 2000); R. Bin Wong, *China Transformed: Historical Change and the Limits of European Experience* (Ithaca: Cornell Univ. Press, 1997).
3. Prefiguring the world environmental history boom of the 1990s were, among others, Lester J. Bilsky, editor, *Historical Ecology* (Port Washington, NY: Kennikat Press, 1980); Piers Blaikie and Harold Brookfield, *Land Degradation and Society* (London: Methuen, 1987); Fernand Braudel, *The Mediterranean and the Mediterranean world in the age of Philip II*, 2 vols. (New York: Harper and Row, 1972–1973); Alfred W. Crosby *The Columbian Exchange: Biological and Cultural Consequences of 1492* (Westport, CT: Greenwood, 1972); A. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900–1900* (Cambridge: Cambridge University Press, 1986); Frank Perlin, *A Forest Journey: The Role of Wood in the Development of Civilization* (Cambridge: Harvard University Press, 1989); J. F. Richards and R. Tucker, editors, *World Deforestation in the Twentieth Century* (Durham: Duke University Press, 1988); R. Tucker and J. F. Richards, editors, *Global Deforestation and the Nineteenth Century World Economy* (Durham, NC: Duke University Press, 1983); Jack Westoby, *Introduction to World Forestry* (Oxford: Basil Blackwell, 1989); Donald Worster, "World without Borders: The Internationalizing of Environmental History," in Kendall E. Bailes, editor, *Environmental History* (Lanham, MD: University Press of America), 661–669; Donald Worster, editor, *The Ends of the Earth: Perspectives on Modern Environmental History* (Cambridge: Cambridge University Press, 1988).
 4. A representative sampling of recent work in modern world environmental history includes Sing Chew, *World Ecological Degradation: Accumulation, Urbanization, and Deforestation 3000 B.C.–A.D. 2000* (Walnut Creek, CA: AltaMira, 2001); Mike Davis, *Late Victorian Holocausts: El Nino Famines and the Making of the Third World* (London: Verso, 2001); Warren Dean, *With Broad Ax and Firebrand: The Destruction of the Brazilian Atlantic Forest* (Berkeley: Univ. of California Press, 1995); Richard Drayton, *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World* (New Haven: Yale University Press, 2001); Mark Elvin and Liu Ts'ui-jung, editors, *Sediments of Time: Environment and Society in Chinese History* (Cambridge: Cambridge University Press, 1998); Brian M. Fagan, *Floods, Famines, and Emperors: El Nino and the Fate of Civilizations* (New York: Basic Books, 1999); John Bellamy Foster, *The Vulnerable Planet: A Short Economic History of the Environment* (New York: Monthly Review, 1994); Harriet Friedmann, "Circle of Growing and Eating: The Political Ecology of Food and Agriculture," in Raymond Grew, editor, *Food in Global History* (Boulder, CO: Westview, 1999): 33–57; Tom Griffiths and Libby Robin, editors, *Ecology and Empire: Environmental History of Settler Societies*. (Seattle: University of Washington Press, 1997); Richard H. Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism, 1600–1860* (Cambridge: Cambridge University Press, 1995); Richard H. Grove, *Ecology, Climate, and Empire: Colonialism and Global Environmental History, 1400–1940* (Cambridge: White Horse Press, 1997); Richard H. Grove and John Chappell, editors,

- El Nino, History, and Crisis: Studies from the Asia-Pacific Region* (Cambridge: White Horse Press, 2000); Richard H. Grove, Vinita Damodaran, and Satpal Sangwan, editors, *Nature and the Orient: The Environmental History of South and Southeast Asia* (New Delhi: Oxford University Press, 1998); J. Donald Hughes, editor, *The Face of the Earth: Environment and World History* (Armonk, NY: M.E. Sharpe, 2000); J. Donald Hughes, *An Environmental History of the World: Humankind's Changing Role in the Community of Life* (New York: Routledge, 2001); Kozo Mayumi, "Temporary Emancipation from the Land: From the Industrial Revolution to the Present," *Ecological Economics* 4/1 (1991): 35–56; J. R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth Century World* (New York: W.W. Norton, 2000); J. R. McNeill, editor, *Environmental History in the Pacific World* (Burlington, VT: Ashgate, 2001); Jason W. Moore, "Environmental Crises and the Metabolic Rift in World-Historical Perspective," *Organization & Environment* 13 (2000): 123–158; J. Moore, "Sugar and the Expansion of the Early Modern World-Economy," *Review: A Journal of the Fernand Braudel Center* 23 (2000): 409–433; J. Moore, "The Crisis of Feudalism: An Environmental History," *Organization & Environment* 15(2002): 296–317; J. Moore, "Nature and the Transition from Feudalism to Capitalism," *Review* 26 (2003 [in press]); Clive Ponting, *A Green History of the World* (New York: St. Martin's, 1991); B. L. Turner II, William C. Clark, Robert W. Kates, John F. Richards, Jessica T. Mathews, and William B. Meyer, editors, *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years* (Cambridge: Cambridge University Press, 1990); Helen Wheatley, editor, *Agriculture, Resources Exploitation, and Environmental Change* (Brookfield, VT: Ashgate, 1997).
5. Consider, for starters, the nearly total absence of social theory in recent world environmental histories (e.g. McNeill, *Something New Under the Sun*; Hughes, *An Environmental History of the World*). These studies often invoke population growth, technological change, and economic development, among others, as causal factors with very little conceptual effort. Theoretical initiatives within environmental history, such as Worster's call for a modes of production approach or Merchant's conception of ecological revolutions, have fallen on deaf ears (Donald Worster, "Transformations of the Earth: Toward an Agroecological Perspective in History," *Journal of American History* 76/4 (1990): 1087–1106; Carolyn Merchant, *Ecological Revolutions* (Chapel Hill: University of North Carolina Press, 1989). Meanwhile, social scientists have made little headway in ecohistorical research. Goldman and Schurman's recent *Annual Review of Sociology* essay, surveying environmental sociology, has nothing to say about environmental history (Michael Goldman and Rachel A. Schurman, "Closing the 'Great Divide': New Social Theory on Society and Nature," *Annual Review of Sociology* 26 (2000): 563–584). Alternatively, Braun and Castree's *Remaking Reality*, which has received considerable attention among geographers and anthropologists especially, offers some useful criticisms of environmental historians such as Worster, but readers will search in vain for an environmental history contribution to this important collection (Bruce Braun and Noel Castree, editors, *Remaking Reality: Nature at the Millennium* (New York: Routledge, 1998)).
 6. James O'Connor, *Natural Causes: Essays in Ecological Socialism* (New York: Guilford, 1998); Braun and Castree, *Remaking Reality*; Richard Peet and Michael Watts, editors, *Liberation Ecologies: Environment, Development, Social Movements* (New York: Routledge, 1996); John Bellamy Foster, "Marx's Theory of

- Metabolic Rift: Classical Foundations for Environmental Sociology," *American Journal of Sociology* 105 (1999): 366–405; John Bellamy Foster, *Marx's Ecology: Materialism and Nature* (New York: Monthly Review Press, 2000).
7. McNeill, *Something New Under the Sun*; Grove, *Green Imperialism*; Davis, *Late Victorian Holocausts*.
 8. New York: Academic Press, 1974. Hereafter, I refer to the first volume as *The Modern World-System*, and to subsequent volumes as *The Modern World-System II, III*.
 9. Riley Dunlap and William Catton, "Struggling with Human Exemptionalism," *American Sociologist* 25/1 (1994): 5–30.
 10. Harriet Friedmann, "What on Earth is the Modern World-System? Foodgetting and Territory in the Modern Era and Beyond," *Journal of World-Systems Research* 6(2000): 480–515; Chew, *World Ecological Degradation*.
 11. Wallerstein, *The Modern World-System I*, 44.
 12. Moore, "Environmental Crises and the Metabolic Rift in World-Historical Perspective."
 13. Wallerstein, *The Modern World-System I*, 33, 36.
 14. Stephen G. Bunker, *Underdeveloping the Amazon* (Urbana: University of Illinois Press, 1985); Chew, *World Ecological Degradation*; Friedmann, "What on Earth is the Modern World-System?"; Groves, *Green Imperialism*; J. Timmons Roberts and Peter Grimes, "Extending the world-system to the whole system: Toward a political economy of the biosphere," in *Ecology and the World-System*, editors, Walter L. Goldfrank, D. Goodman, and A. Szasz (Westport, CT: Greenwood, 1999): 59–83; David A. Smith, "Uneven Development and the Environment: Toward a World-System Perspective," *Humboldt Journal of Social Relations* 20 (1994): 151–175; Worster, "World Without Borders."
 15. Sing Chew, "For Nature: Deep Greening World-Systems Analysis for the 21st Century," *Journal of World-Systems Analysis* 3/3 (1997): 383.
 16. Friedmann, "What on Earth is the Modern World-System?," 501.
 17. Perry Anderson, *Passages from Antiquity to Feudalism* (London: New Left Books, 1974); Harry Miskimin, *The Economy of Early Renaissance Europe, 1300–1460* (New York: Prentice-Hall, 1975); M. M. Postan, *Medieval Economy and Society*, (New York: Pelican, 1972).
 18. See especially Robert Brenner, "The Origins of Capitalism: A Critique of Neo-Smithian Marxism," *New Left Review* 104 (1977): 25–92.
 19. See esp. Karl Marx, *The Grundrisse* (New York: Vintage, 1973), 99–100.
 20. Among the widely-cited criticisms along these lines, see Stephen J. Stern, "Feudalism, Capitalism, and the World-System in the Perspective of Latin America and the Caribbean," *American Historical Review* 93 (1988): 829–873.
 21. "But 'Europe' must not be reified. There was no central agency which acted in terms of these long-term objectives. The real decisions were taken by groups of men acting in terms of their immediate interests" (Wallerstein, *The Modern World-System I*, 51).
 22. See David Harvey, *Spaces of Hope* (Berkeley: University of California Press, 2000); Neil Smith, *Uneven Development* (Oxford: Blackwell, 1984); Edward W. Soja, *Postmodern Geographies* (London: Verso, 1989).
 23. Wallerstein, *The Modern World-System I*, 68, 77.
 24. *Ibid.*, 35.
 25. *Ibid.*, 44.
 26. "The phrase 'political ecology' combines the concerns of ecology and a broadly

defined political economy. Together this encompasses the constantly shifting dialectic between society and land-based resources, and also within classes and groups within society itself" (Blaikie and Brookfield, *Land Degradation and Society*, 17).

27. Wallerstein, *The Modern World-System I*, 34.
28. *Ibid.*, 35.
29. *Ibid.*, 48.
30. *Ibid.*, 104, 100–101, 112.
31. "That one or two percent [of Europe's total consumption provided by Baltic grain] was nevertheless exceptionally important, both because of the prosperity it brought to such seafarers as the Dutch and because it represented the margin of survival for capital cities like Lisbon" (Charles Tilly, "Food Supply in Early Modern Europe," in Charles Tilly, editor, *The Formation of National States in Early Modern Europe*, (Princeton: Princeton University Press, 1975), 416 quoted in Wallerstein, *The Modern World-System I*, 76.
32. *Ibid.*, 75–76.
33. *Ibid.*, 42–43.
34. I use the terms "inner" and "outer" expansion, following Terence K. Hopkins and Immanuel Wallerstein, "Patterns of development of the modern world-system," *Review* 1/2 (1977), 125: "The literature on agricultural history has indicated a clear pattern over time of 'inner' expansion, in the sense that not all the areas physically located inside the outer boundaries of the world-economy had necessarily been from the outset involved in the social economy. There were 'subsistence redoubts.' It is clear that, as a process, the incorporation of areas at the outer edges and the areas that were redoubts inside it were the same phenomenon economically, even if it had a different definition juridically and perhaps different prerequisites politically."
35. Wallerstein, *The Modern World-System I*, 48, 51, emphasis added.
36. *Ibid.*, 24.
37. *Ibid.*, 21.
38. *Ibid.*, 24.
39. *Ibid.*, 22, 35–36.
40. *Ibid.*, 188, 36, n. 78.
41. *Ibid.*, 89–90.
42. *Ibid.*, 49–50.
43. *Ibid.*, 52.
44. *Ibid.*, 68, 77.
45. *Ibid.*, 42.
46. *Ibid.*, 76, emphasis added.
47. Fernand Braudel, *The Perspective of the World* (New York: Harper and Row, 1984), 157–174.
48. See Wallerstein's approving quotation of Gustaf Utterstrom, "Climate Fluctuations and Population Problems in Early Modern Europe," *Scandinavian Economic History Review* 3 (1955): 44. "The food situation in the Mediterranean area would in all probability have been much more serious if the flow of precious metals from America had not provided means of payment for the large purchases of grain" (quoted in *The Modern World-System I*, 217, n. 252).
49. G. B. Masefield, "Crops and Livestock," in E. E. Rich and C. H. Wilson, editors, *The Cambridge Economic History of Europe IV* (Cambridge: Cambridge University Press, 1967), 276, quoted in Wallerstein, *The Modern World-System I*, 44–45, n. 108.

50. Here Wallerstein offers a Marxist rather than Malthusian conception of resource strain. The many-sided demands of capital, rather than an inexorably rising population, determine the nature and degree of resource strain.
51. Wallerstein, *The Modern World-System I*, 42.
52. *Ibid.*, 98–99, 111–112, 121–122, 129.
53. *Ibid.*, *The Modern World-System I*, 107.
54. Wallerstein, *The Modern World-System II: Mercantilism and the Consolidation of the European World-Economy 1600–1750* (New York: Academic Press, 1980), 146.
55. Wallerstein, *The Modern World-System I*, 44–45; *The Modern World-System II*, 161–162.
56. Wallerstein, *The Modern World-System I*, 281, 281, n. 276.
57. *Ibid.*, 281.
58. *Ibid.*, 193, n. 138.
59. Fernand Braudel, *Le Mediterranee et le monde Meditteraneen a l'epoque de Philippe II*, 2e ed. revue et augmente, 2 vol. (Paris: Lib. Armand Colin, 1966) quoted in Wallerstein, *The Modern World-System I*, 45, n. 109.
60. Wallerstein, *The Modern World-System I*, 45.
61. Wallerstein, *The Modern World-System II*, 101.
62. Wallerstein, *The Modern World-System I*, 45.
63. Wallerstein, *The Modern World-System II*, 75.
64. Wocjich Szczygielski, “Die Okonomische Aktivitat de Polnischen Adels im 16.–18. Jarhundert,” *Studia Historia Economicae* 2 (1967): 94, quoted in Wallerstein, *The Modern World-System II*, 133, n. 16.
65. Wallerstein, *The Modern World-System II*, 161–162.
66. Wallerstein, *The Modern World-System I*, 102.
67. Wallerstein, *The Modern World-System II*, 162, 162, n. 168.
68. Wallerstein, *The Modern World-System II*, 162; Pierre Chaunu, “Bresil et l’Atlantique au XVIIe Siecle,” *Annales E.S.C.* 17/6 (1961): 1176–1207.
69. Wallerstein, *The Modern World-System I*, 89.
70. Wallerstein, *The Modern World-System I*, 44; Wallerstein, *The Modern World-System II*, 162, n. 164.
71. Wallerstein, *The Modern World-System II*, 132–133, emphasis added; internal quotation from Szczygielski, “Die Okonomische Aktivitat de Polnischen,” 94.
72. Karl Marx, *Capital*, Vol. I (New York: Vintage, 1977), 283, 636–638. Also see below.
73. In terms of Marx’s political economy, this line of thinking is developed furthest by Paul Burkett, *Marx and Nature: A Red and Green Perspective* (New York: St. Martin’s, 1999). Moore, “Nature and the Transition from Feudalism to Capitalism,” develops these themes historically.
74. Historical studies of consumption relations as a socio–physical moment of capital accumulation are not well developed. But see Raymond Grew, editor, *Food in Global History* (Boulder, CO: Westview, 2000); and Sidney W. Mintz, *Sweetness and Power* (New York: Penguin, 1985). Food consumption provides a particularly interesting angle of vision upon the dialectical relations between bodily space and the socio–spatial division of labor. The rise of “food consumption politics” as an emergent social movement (around such issues as genetically modified foods and recombinant bovine growth hormone) will undoubtedly spur new research into consumption relations as an aspect of world environmental history.
75. Wallerstein, *The Modern World-System I*, 90.
76. *Ibid.*, 36.

77. *Ibid.*, 44.
78. Karl Helleiner, "The Population of Europe from the Black Death to the Eve of the Vital Revolution," in E. E. Rich and C. H. Wilson, editors, *The Cambridge Economic History of Europe IV* (Cambridge: Cambridge University Press, 1967), 68–69, quoted in Wallerstein, *The Modern World-System I*, 36, n. 78.
79. Wallerstein, *The Modern World-System I*, 109.
80. For example Foster, *The Vulnerable Planet*; Hughes, *An Environmental History of the World*; Ponting, *A Green History of the World*.
81. Wallerstein, *The Modern World-System I*, 35.
82. *Ibid.*, 44.
83. What is surprising is that for all the discussions of "ecological imperialism" (Crosby, *Ecological Imperialism*), even within the world-historical perspective, there has been little serious pursuit of this line of thinking. But see Jason W. Moore, "Ecology and Imperialism," *Monthly Review*, forthcoming (2003).
84. See respectively, Brenner, "The Origins of Capitalism," and Dale Tomich, "World of Capital/Worlds of Labor: A Global Perspective," in J. R. Hall, editor, *Reworking Class* (Ithaca: Cornell University Press, 1997), 287–311.
85. Hughes, *An Environmental History of the World*.
86. Ponting, *A Green History of the World*; Chew, *World Ecological Degradation*; McNeill, *Something New Under the Sun*; for a suggestive exception, see Davis, *Late Victorian Holocausts*.
87. Wallerstein, 1974: 126. Wallerstein does not ignore the town-country division of labor but rather deploys a weak conception. For exceptions, see his approving quotation from Braudel on agricultural improvement and urbanization, as well as his discussion of the English "town bourgeois" whose agricultural investments "desolat[ed] the land" (*The Modern World-System I*, 42n. 107). Note also that the Braudel of *The Mediterranean* offers a much stronger account of town-country relations than the Braudel of the *Civilization and Capitalism* trilogy. "Capitalism and towns were basically the same thing in the West" (Fernand Braudel, *The Structures of Everyday Life* (New York: Harper and Row, 1981], 514).
88. See Bunker, *Underdeveloping the Amazon*.
89. Karl Marx, *Theories of Surplus Value*, Part III (Moscow: Progress Publishers, 1971), 488–489, 268–269.
90. Karl Marx, *The Economic and Philosophic Manuscripts of 1844* (Moscow: Progress, 1959), 77.
91. Marx, *Capital*, vol. I, 638.
92. Burkett, *Marx and Nature*, 84.
93. Worster, "Transformations of the Earth"; William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W.W. Norton, 1991).
94. Jason W. Moore, "Braudel's Eco-Historical Geographies: Time, Space, and Nature in the Early Modern World," unpublished ms., Department of Geography, University of California, Berkeley, 2002.
95. Harry Braverman, *Labor and Monopoly Capital* (New York: Monthly Review, 1974), esp. 181–182. My approach here follows the spirit of Braverman's interpretation of the labor process, which necessarily (although Braverman did not see this) entails a radical simplification not just of concrete labors but of the ecological wealth that the former reshapes: "We see that this abstraction from the concrete forms of labor ... which Marx employed as means of clarifying the value of commodities (according to the share of such general human labor they embody), is not something that exists only in the pages of the first chapter of *Capital*, but

exists as well in the mind of the capitalist, the manager, the industrial engineer. It is precisely their effort and *métier* to visualize labor not as a total human endeavor, *but to abstract from all its concrete qualities in order to comprehend it as universal and endlessly repeated motions ...* [I]n this form [labor] comes ever closer to corresponding, in life, to the abstraction employed by Marx in analysis of the capitalist mode of production” (*ibid*).

96. David Harvey, “The Nature of the Environment: The Dialectics of Social and Environmental Change,” in Leo Panitch and Ralph Miliband, editors, *Socialist Register 1993* (London: Merlin, 1993), 6. This exchangeability, as Harvey’s reference to property rights suggests, hinges on recurrent waves of primitive accumulation. What in “*primitive accumulation* appears as a distinct historical process[,] ... [a]ccumulation merely presents as a *continuous process*” (Marx, *Theories of Surplus Value*, III, 272). A “global ecological history might be written” of this continuous process – namely, the use of state power (law above all) to “reorganise[e] alien agrarian modes of production” – E. P. Thompson once suggested (E. P. Thompson, *Customs in Common* (New York: The New Press, 1991), 164). From this standpoint, the state plays a crucial role in enabling the radical simplification of nature, and is sometimes a direct agent (on this latter, see James C. Scott, *Seeing Like A State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale Univ. Press, 1998), 11–52).
97. Foster, “Marx’s Theory of Metabolic Rift”; Karl Marx, *Capital*, vol. III (New York: Penguin, 1981), 949.
98. Marx, *Capital*, vol. I, 283, 636–638.
99. Harvey, *Spaces of Hope*.
100. An expanded discussion of these themes may be found in Moore, “Crisis of Feudalism” and “Nature and the Transition from Feudalism to Capitalism.”
101. Wallerstein, *The Modern World-System I*, 24, emphasis added.
102. M.N. Pearson, *The Portuguese in India* (Cambridge: Cambridge University Press, 1987).
103. J.H. Elliot, *Imperial Spain 1469–1716* (New York: Mentor, 1966), 180; Fernand Braudel and Frank Spooner, Frank (1967). “Prices in Europe from 1450 to 1750,” in E. E. Rich and C. H. Wilson, editors, *The Cambridge Economic History of Europe*, vol. IV (Cambridge: Cambridge Univ. Press,) 445; Geoffrey Parker, “The Emergence of Modern Finance in Europe, 1500–1730,” in Carlo M. Cipolla, editor, *The Fontana Economic History of Europe II* (London: Fontana, 1974), 527–528.
104. Aldo de Maddalena, “Rural Europe 1500–1700,” in Carlo M. Cipolla, editor, *The Fontana Economic History of Europe II: The Sixteenth and Seventeenth Centuries* (London: Fontana, 1974), 308; also Anderson, *Lineages*, 285.
105. Access to American silver was almost certainly a precondition of Dutch financial power in the Baltic. Precious metals financed some two-thirds of northwestern Europe’s trade with Baltic in the sixteenth century. See John H. Munro, “Patterns of Trade, Money, and Credit,” in Thomas A. Brady, Jr., Heiko A. Oberman, and James D. Tracy, editors, *Handbook of European History, 1400–1600 Vol. I: Late Middle Ages, Renaissance, and Reformation: Structures and Assertions* (Grand Rapids, MI: Wm. B. Eerdmans Publishing Co., 1996), 171.
106. Wallerstein, *The Modern World-System I*, 121–122
107. Kristof Glamann, “European Trade 1500–1700,” in Carlo M. Cipolla, editor, *The Fontana Economic History of Europe II* (London: Fontana Books), 427–576; Braudel, *The Structures of Everyday Life*.
108. Tilly, “Food Supply in Early Modern Europe”; Maria Bogucka, “North European

- Commerce as a Solution to Resource Shortage in the Sixteenth–Eighteenth Centuries,” in W. N. Parker and Antoni Maczak, editors, *Natural Resources in European History* (Washington, D.C.: Resources for the Future, Inc., 1978), 12.
109. If the amount of grain exported from eastern Europe in the mid–sixteenth century “was small in proportion to total consumption ... it relieved pressure at vital points, notably where the Low Countries industry and Andalusian [Spanish] viniculture were producing for European markets *on a scale that could only be maintained by importing food for their own people*” (Ralph Davis, *The Rise of the Atlantic Economies* [Ithaca, NY: Cornell Univ. Press, 1973], 19, emphasis added; see also Richard C. Hoffmann, “Frontier Foods for Late Medieval Consumers: Culture, Economy, Ecology,” *Environment and History* 7 (2001): 131–167.
 110. Philip D. Curtin, *The Plantation Complex in World History* (Cambridge: Cambridge Univ. Press, 1990).
 111. My conception of the commodity frontier builds upon Hopkins and Wallerstein’s concept of the commodity chain, which “refers to a network of labor and production processes whose end result is a finished commodity” (Terence K. Hopkins and Immanuel Wallerstein, “Commodity Chains in the World-Economy Prior to 1800,” *Review* 10/1 (1986): 157–170). Although commodity chain analysis typically begins with the finished product, tracking frontier expansion requires a focus on primary production. The point of commodity chain analysis is two–fold: 1) to determine the boundaries and shifting configuration of the world–economy’s interdependent division of labor; and 2) to analyze shifts among core, periphery, and semiperiphery over time. While state actors attempt to shape the system’s division of labor to their advantage, the primary organizing mechanisms are commodity chains, whose operations are transnational. This approach permits an end–run around traditional conceptions of frontier expansion, which accept the national or imperial sphere rather than the world–economy as the primary unit of analysis (see Moore, “Sugar and the Expansion of the Early Modern World-Economy.”)
 112. Postan, *Medieval Economy and Society*; Miskimin, *Economy of Early Renaissance Europe*; Anderson, *Passages*; Moore, “Crisis of Feudalism”; Moore, “Nature and the Transition from Feudalism to Capitalism.”
 113. Barbara L. Solow, “Capitalism and Slavery in the Exceedingly Long Run,” in Barbara L. Solow and Stanley L. Engerman, editors, *British Capitalism and Caribbean Slavery: The Legacy of Eric Williams* (Cambridge: Cambridge Univ. Press, 1987), 51–77.
 114. Robert P. Brenner, “The Low Countries in the Transition to Capitalism,” *Journal of Agrarian Change* 1(2001): 169–241.
 115. Bartolome Yun, “Economic Cycles and Structural Changes,” in Thomas A. Brady, Jr., Heiko A. Oberman, and James D. Tracy, editors, *Handbook of European History, 1400–1600 Vol. I: Late Middle Ages, Renaissance, and Reformation: Structures and Assertions* (Grand Rapids, MI: Wm. B. Eerdmans Publishing Co., 1996), 119.
 116. John U. Nef, *The Conquest of the Material World* (New York: Meridian, 1964), 42 and 31–75 *passim*.
 117. Hughes, *An Environmental History of the World*, 63–66.
 118. Nef, *The Conquest of the Material World*, 44.
 119. Georgius Agricola, *De Re Metallica* (Hoover, NY: Dover Publications, 1950 reprint, 1556 original), 8.
 120. Vaclav Smil, *Energy in World History* (Boulder, CO: Westview Press, 1994), 156.

121. Carlo M. Cipolla, *Before the Industrial Revolution: European Society and Economy, 1000–1700* (New York: Norton, 1976), 228–230.
122. N.G.S. Pounds, *An Historical Geography of Europe* (Cambridge: Cambridge University Press, 1990), 199; also Ian Blanchard, “Resource Depletion in European Mining and Metallurgical Industries, 1400–1800,” in W. N. Parker and Antoni Maczak, editors, *Natural Resources in European History* (Washington, D.C.: Resources for the Future, Inc., 1978), 106.
123. Declining yields figured in terms of labor productivity, see Blanchard, “Resource Depletion,” 88.
124. Karl Appuhn, “Inventing Nature: Forests, Forestry, and State Power in Renaissance Venice,” *Journal of Modern History* 72 (2000): 865; see also Cipolla, *Before the Industrial Revolution*.
125. H.C. Darby, “The Clearing of Woodland in Europe,” in William L. Thomas, Jr., editor, *Man’s Role in Changing the Face of the Earth* (Chicago: Univ. of Illinois Press, 1956), 183–216; Hermann Kellenbenz, “Technology in the Age of the Scientific Revolution 1500–1700,” in Carlo M. Cipolla, editor, *The Fontana Economic History of Europe II* (London: Fontana Books, 1974), 257.
126. Peter Blickle, *The Revolution of 1525: The German Peasants’ War from a New Perspective* (Baltimore: The Johns Hopkins University Press, 1981), 19–21, 120–122; Westoby, *Introduction to World Forestry*, 54–58, 60–61. On the concentration of workers in the mining camps, see Fernand Braudel, *The Wheels of Commerce* (New York: Harper and Row, 1982), 323–325; Roger Mols, S. J., “Population in Europe 1500–1700,” in Carlo M. Cipolla, editor, *The Fontana Economic History of Europe II* (London: Fontana Books, 1974), 40; Kellenbenz, “Technology in the Age of the Scientific Revolution 1500–1700.” The European-wide assault on forests had one further impact on social unrest. In Venice and elsewhere, ensuring the supply of firewood for heating and cooking was a “perpetual problem” that carried with it “the potential for civic unrest if the supply failed” (Appuhn, “Inventing Nature,” 866–867).
127. Braudel, *The Wheels of Commerce*, 325; see also Blanchard, “Resource Depletion in European Mining and Metallurgical Industries, 1400–1800,” 89–90; Rondo Cameron, *A Concise Economic History of the World: From Paleolithic Times to the Present* (Oxford: Oxford Univ. Press, 1993), 118–119.
128. See Elizabeth Dore, “Environment and Society: Long-Term Trends in Latin American Mining,” *Environment and History* 6 (2000): 1–29.
129. Brading and Cross, “Colonial Silver Mining,” 545.
130. Alejandro Portes, “Urban Latin America: The Political Condition from Above and Below,” in Janet Abu-Lughod and Richard Hay, Jr., editors, *Urbanization in the Third World* (Chicago: Maaroufa, 1977), 61; see also Jorge E. Hardo and Carmen Aranovich, “Urban Scales and Functions in Spanish America Toward the Year 1600: First Conclusions,” *Latin American Research Review* 5/3 (1970): 57–91.
131. Portes, “Urban Latin America,” 61.
132. Madhav Gadgil and Ramachandra Guha, *This Fissured Land: An Ecological History of India* (Berkeley: University of California Press, 1992), 121; for a world-historical conception of sequential overexploitation, see Moore, “Environmental Crises and the Metabolic Rift in World-Historical Perspective.”
133. Ward Barrett, “World Bullion Flows, 1450–1800,” in *The Rise of Merchant Empires: Long Distance Trade in the Early Modern World 1350–1750*, James D. Tracy, editor (Cambridge: Cambridge University Press, 1990), 225.
134. Richard L. Garner, “Long-Term Silver Mining Trends in Spanish America: A

- Comparative Analysis of Peru and Mexico,” *American Historical Review* 93 (1988): 911; Brading and Cross, “Colonial Silver Mining,” 1972, 571.
135. Eduardo Galeano, *Open Veins of Latin America: Five Centuries of Pillage of a Continent* (New York: Monthly Review Press), 31.
 136. Huancavelica and Potosi, declared Peru’s viceroy in 1648, were “like two poles which support this kingdom [Peru] and that of Spain.” Indeed, Huancavelica “had the distinction of being unique and irreplaceable, so that its preservation is a matter of even greater concern [than that of Potosi]” (Quoted in Arthur Preston Whitaker, *The Huancavelica Mercury Mine* [Cambridge: Harvard University Press, 1941], 3).
 137. Steve J. Stern, “Feudalism, Capitalism, and the World-System in the Perspective of Latin America and the Caribbean,” *American Historical Review* 93 (1988): 850–851; Jeffrey Austin Cole, *The Potosi Mita, 1573–1700: Compulsory Indian Labor in the Andes* (Stanford: Stanford University Press, 1985), 3–4; Gwendolin Ballantine Cobb, *Potosi and Huancavelica: Economic Bases of Peru, 1545–1640*, doctoral dissertation (Department of History, University of California, Berkeley, 1947), 117–199. On the profitability of the coca trade, see Lyle N. McAlister, *Spain and Portugal in the New World 1492–1700* (Minneapolis: University of Minnesota Press, 1984), 222–223.
 138. “By 1568 the value of the Potosi ore had dropped from one hundred marks a quintal [approximately 500 pounds] down to two marks” (Cobb, *Potosi and Huancavelica*, 124).
 139. Peter J. Bakewell, “Mining,” in L. Bethell, editor, *Colonial Spanish America* (Cambridge: Cambridge Univ. Press, 1987), 239.
 140. Cole, *The Potosi Mita*, 4.
 141. Kenneth J. Andrien, *Andean Worlds: Indigenous History, Culture, and Consciousness under Spanish Rule, 1532–1825* (Albuquerque: University of New Mexico Press, 2001), 49.
 142. McNeill, *The Pursuit of Power* (Chicago: University of Chicago Press, 1982), 109.
 143. Parker, “The Emergence of Modern Finance,” 561, 568–569; Robert S. DuPlessis, *Transitions to Capitalism in Early Modern Europe* (Cambridge: Cambridge Univ. Press, 1997), 50–53; McNeill, *The Pursuit of Power*.
 144. Carla Rahn Phillips, “Time and Duration: A Model for the Economy of Early Modern Spain,” *American Historical Review* 92 (1987): 531–562; DuPlessis, *Transition to Capitalism*. Wallerstein, as we have seen, points to the agro–ecological moment of this crisis (*The Modern World-System II*, 146).
 145. Steve J. Stern, *Peru’s Indian Peoples and the Challenge of Spanish Conquest: Huamanga to 1640* (Madison: University of Wisconsin Press, 1982), 82; Carlos Sempat Assadourian, “The Colonial Economy: The Transfer of the European System of Production to New Spain and Peru,” *Journal of Latin American Studies* 24 (1992, Issue Quincentenary Supplement), 56–58.
 146. Cole, *The Potosi Mita*, 18.
 147. Bakewell, “Mining,” 214.
 148. Alan K. Craig, “The Ingenious *Ingenios*: Spanish Colonial Water Mills at Potosi,” in Kent Mathewson, editor, *Culture, Form, and Place: Essays in Cultural and Historical Geography* (Baton Rouge: Louisiana State University Press, 1993), 125; Bakewell, “Mining,” 218.
 149. Bakewell, “Mining,” 242.
 150. Kendall W. Brown and Alan K. Craig, “Silver Mining at Huantajaya, Viceroyalty of Peru,” in Alan K. Craig and Robert C. West, editors, *In Quest of Mineral*

- Wealth: Aboriginal and Colonial Mining and Metallurgy in Spanish America* (Baton Rouge: Louisiana State University, 1994), 305.
151. Craig, "The Ingenious *Ingenios*," 145.
 152. Bakewell, *Miners of the Red Mountain*, 149.
 153. Newson, "Indian Population Patterns in Colonial Spanish America," *Latin American Research Review* 20(1985): 55.
 154. Bakewell, *Miners of the Red Mountain*, 152.
 155. Peter E. S. Freund and Meredith McGuire, *Health, Illness, and the Social Body: A Critical Sociology*, 3d ed. (Upper Saddle River, NJ: Prentice-Hall, 1999), 94.
 156. Jerome O. Nriagu (1994). "Mercury Pollution from the Past Mining of Gold and Silver in the Americas," *The Science of the Total Environment* 149 (1994), 167.
 157. James J. Parsons, "The Cork Oak Forests and the Evolution of the Cork Industry in Southern Spain and Portugal," *Economic Geography* 38(1962): 200–201; Kendall W. Brown, "Workers' Health and Colonial Mercury Mining at Huancavelica, Peru," *The Americas* 57 (2000): 467. By the early seventeenth century, wood scarcity led to the use of icho, a coarse grass, in mercury refining (Cobb, *Potosi and Huancavelica*, 62).
 158. Galeano, *Open Veins of Latin America*, 52.
 159. Cole, *The Potosi Mita*, 29.
 160. Bakewell, "Mining," 214.
 161. Peter J. Bakewell, *Miners of the Red Mountain: Indian Labor in Potosi, 1545–1650* (Albuquerque: Univ. of New Mexico Press, 1984), 24; Bakewell, "Mining," 218; Carl Sauer, *Selected Essays, 1963–1975* (Berkeley, CA: Turtle Island Foundation, 1981), 50.
 162. Dore, "Environment and Society: Long-Term Trends in Latin American Mining," 8–9; Gwendolin Cobb, "Supply and Transportation for the Potosi Mines, 1545–1640," *Hispanic American Historical Review* 29 (1949), 25–45.
 163. Cobb, *Potosi and Huancavelica*, 80.
 164. Madrid, of roughly comparable size but with a more favorable climate, consumed some 12,500 tons of charcoal each year for heating and cooking in 1630. See Jan de Vries, *The Economy of Europe in an Age of Crisis, 1600–1750* (Cambridge: Cambridge University Press, 1976), 164.
 165. J.R. McNeill, *The Mountains of the Mediterranean World: An Environmental History* (Cambridge: Cambridge Univ. Press, 1992), 352; also Wilma A. Dunaway, "Incorporation of Mountain Ecosystems into the Capitalist World-System," *Review* 19/4 (1996): 358–359.
 166. Edmund Burke III, "Environment and World History, 1500–2000," in Edmund Burke III and Kenneth Pomeranz, editors, *The Environment and World History 1750–2000* (Berkeley: Univ. of California Press, in press); Sauer, *Selected Essays*, 353.
 167. Peter J. Bakewell, "Mining," in L. Bethell, editor, *Colonial Spanish America* (Cambridge: Cambridge Univ. Press, 1987), 217–218.
 168. Kellenbenz, "Technology in the Age of the Scientific Revolution 1500–1700," 257; see also Peter J. Bakewell, *Silver Mining and Society in Colonial Mexico: Zacatecas, 1546–1700* (Cambridge: Cambridge Univ. Press, 1971), 146–147; Enrique Semo, *The History of Capitalism in Mexico: Its Origins 1521–1763* (Austin: Univ. of Texas Press, 1993), 76.
 169. Alvaro Sanchez-Crispin, "The Territorial Organization of Metallic Mining in New Spain," in Alan K. Craig and Robert C. West, editors, *In Quest of Mineral Wealth: Aboriginal and Colonial Mining and Metallurgy in Spanish America (Geoscience and Man, vol. 33)*, (Baton Rouge: Louisiana State University, 1994), 166.

170. Quoted in Robert C. West, "Early Silver Mining in New Spain, 1531–1555," in P. J. Bakewell, editor, *Mines of Silver and Gold in the Americas* (Brookfield, VT: Varorium/Ashgate, 1997), 68–69.
171. Kellenbenz, "Technology in the Age of the Scientific Revolution 1500–1700," 257.
172. Robert C. West, "The Mining Economy of Sinaloa: 400 Years of a Prevailing Lifeway," in *Latin American Geography: Historical–Geographical Essays, 1941–1998* (Baton Rouge: Louisiana State University Press, 1998), 184.
173. Bakewell, "Mining," 218.
174. D.A. Brading and Harry E. Cross, "Colonial Silver Mining: Mexico and Peru," *Hispanic American Historical Review* 52 (1972): 556, 574; Assadourian, "The Colonial Economy," 59; Sanchez–Crispin, "The Territorial Organization of Metallic Mining in New Spain," 184.
175. West, "Early Silver Mining in New Spain, 1531–1555," 69.
176. Wallerstein, *The Modern World-System II*, 153.
177. Enrique Tandeter, "Forced and Free Labor in Late Colonial Potosi," *Past and Present* 93 (1981): 104.
178. Stern, *Peru's Indian Peoples*, 84.
179. Tandeter, 104. In this respect, the toxic exploitation of mitayos prefigured the high mortality rates among indentured servants in British America a century later.
180. Cole, *The Potosi Mita*, 23–24.
181. Cole, *The Potosi Mita*, 24–25; Tandeter, 104–105; Cobb, *Potosi and Huancavelica*, 86–89.
182. John Howland Rowe, "The Incas under Spanish Colonial Institutions," *Hispanic American Historical Review* 37/2 (1957): 174.
183. Quoted in Bakewell, *Miners of the Red Mountain*, 145.
184. Cobb, *Potosi and Huancavelica*, 77.
185. Brown, "Workers' Health and Colonial Mercury Mining," 468.
186. Brown, "Workers' Health and Colonial Mercury Mining," 478. A similar situation prevailed above-ground, for workers employed in Huancavelica's refining ovens. Here male workers breathed mercury vapors, and their wives often worked alongside to collect the volatilized mercury (*ibid.*, 480–481).
187. Brown, "Workers' Health and Colonial Mercury Mining," 472, quote from note 19.
188. Brown, "Workers' Health and Colonial Mercury Mining," 495.
189. Brown, "Workers' Health and Colonial Mercury Mining," 470–471; also Katherine V. Fox, "Pedro Muniz, Dean of Lima, and the Indian Labor Question," *Hispanic American Historical Review* 42/1 (1962): 63–88; Galeano, *Open Veins*, 50; Stern, *Peru's Indian Peoples*, 85.
190. Brown, "Workers' Health and Colonial Mercury Mining," 492.
191. Brown, "Workers' Health and Colonial Mercury Mining," 488.
192. Nriagu, "Mercury Pollution," 174. Similarly large volumes of mercury appear to have been dumped in Mexico (Acosta y Asociados, *Inventory of Sites in Mexico with Elevated Concentrations of Mercury: Preliminary Draft Report* [Agua Prieta, Sonora, Mexico: Acosta y Asociados, 2001]).
193. Project Underground, "Mercury Madness," [<http://www.1849.org/ggg/mercury.html>] (no date).
194. Gonzalo Gomez de Cervantes, *La Vida Economic y Social de Nueva Espana al Finalizar el Siglo XVI* (Mexico City: Antigua Libreria Robredo, 1969, original published in 1599), 150–155, emphasis added, selections translated and reproduced in Ramon Sanchez Flores, "Technology of Mining in Colonial Mexico: Installations, Tools, Artifacts and Machines Used in the Patio Press, Sixteenth to Eight-

- eenth Centuries,” in Alan K. Craig and Robert C. West, editors, *In Quest of Mineral Wealth: Aboriginal and Colonial Mining and Metallurgy in Spanish America*, (Baton Rouge: Louisiana State University Press, 1994), 151.
195. It is impossible to know precisely how much mercury flowed into local hydro-systems. My figures rely on Nriagu’s estimates of overall “mercury loss” in Latin American silver mining: over 400 *tons* a year between 1580 and 1640 (“Mercury Pollution,” 174). Peru’s share amounted to over 300 tons annually in this period. Recent studies of mercury contamination suggest that some 55–60 percent of this mercury loss “was released to the atmosphere,” while the rest poured into the ground and aquatic ecosystems (*ibid.*, 179; also see N. Frery, R. Maury–Brachet, E. Maillot, M. Deheeger, B. de Merona, Alain Boudou, “Gold–Mining Activities and Mercury Contamination of Native Amerindian Communities in French Guiana: Key Role of Fish in Dietary Uptake,” *Environmental Health Perspectives* 109/5 (2001): 449–470.
 196. Tim Stephens, “Mercury: A Toxic Legacy,” *UC Santa Cruz Review* 38/3 (2001): 20.
 197. Erica Schoenberger and Ellen Silbergeld, “The Social and Environmental Costs of Gold Mining: Some Issues of Regulation and Scale,” unpublished paper, Department of Geography and Environmental Engineering, The Johns Hopkins University, no date [2000]; also Dore, “Environment and Society”; Nriagu, “Mercury Pollution.”
 198. Stern, *Peru’s Indian Peoples*, 82.
 199. Bakewell, “Mining,” 222.
 200. Rowe, “The Incas under Spanish Colonial Institutions,” 156; Cole, *The Potosi Mita*, 2; Ramirez, “The ‘Dueno de Indios’: Thoughts on the Consequences of the Shifting Bases of Power of the ‘Curaca de los Viejos Antiguos’ under the Spanish in Sixteenth–Century Peru,” *Hispanic American Historical Review* 67 (1987): 597.
 201. Daniel W. Gade, “Landscape, System, and Identity in the Post–Conquest Andes,” *Annals of the Association of American Geographers* 82 (1992): 472.
 202. Karl Marx, *The Grundrisse* (New York: Vintage, 1973), 479.
 203. Andrien, *Andean Worlds*, 57.
 204. Ramirez, “The ‘Dueno de Indios,’” 598; also Susan Elizabeth Ramirez, *The World Turned Upside Down: Cross–Cultural Contact and Conflict in Sixteenth–Century Peru* (Stanford: Stanford Univ. Press, 1996), 71–72.
 205. Stern, *Peru’s Indian Peoples*, 5.
 206. Eric R. Wolf, *Europe and the People without History* (Berkeley: University of California Press, 1982), 59.
 207. Wolf, *Europe*; Brooke Larsen, *Cochabamba 1550–1900: Colonialism and Agrarian Transformation in Bolivia*, 2nd edition (Durham: Duke Univ. Press, 1998), 19–20; John V. Murra, “Andean Societies,” *Annual Review of Anthropology* 13 (1984): 119–141; Ricardo Godoy, “The Evolution of Common–Field Agriculture in the Andes: A Hypothesis,” *Comparative Studies in Society and History* 33 (1991): 400.
 208. Wolf, *Europe and the People without History*, 134–135; also Godoy, “The Evolution of Common–Field Agriculture in the Andes,” 404–405; Karl S. Zimmerer, “Rescaling Irrigation in Latin America: The Cultural Images and Political Ecology of Water Resources,” *Ecumene* 7 (2000): 150–175.
 209. Joan Thirsk, “The Common Fields,” *Past and Present* 29(1964): 3–25.
 210. Godoy, “The Evolution of Common–Field Agriculture in the Andes,” 396–398, 408–409; Gade, “Landscape, System, and Identity in the Post–Conquest Andes,” 467.
 211. Gade, “Landscape, System, and Identity in the Post–Conquest Andes,” 469.

212. Eric R. Wolf, *Sons of the Shaking Earth* (Chicago: Univ. of Chicago Press, 1959), 198–199, emphasis added. In this passage, Wolf is writing about colonial Mexico, where the impact of stockraising was unquestionably greater than in the Andes. Yet, I suggest that the difference between the two regions is one of degree rather than kind.
213. “[A]s soon as one looks at the question of grain, one realizes what a complicated phenomenon it is. It would be better to put it in the plural – *los panes*, as so many Spanish texts say.... [W]heat was never grown by itself. Despite its great age, even older cereals grew alongside it” (Braudel, *Structures*, 109).
214. Keith, *Conquest and Agrarian Change: The Emergence of the Hacienda System of the Peruvian Coast* (Cambridge: Harvard University Press, 1976), 66.
215. Gade, “Landscape, System, and Identity in the Post–Conquest Andes,” 465.
216. Assadourian, “The Colonial Economy,” 67.
217. Godoy, “The Evolution of Common–Field Agriculture in the Andes,” 407; Gade, “Landscape, System, and Identity in the Post–Conquest Andes,” 465–466.
218. Fernand Braudel, *Afterthoughts on Material Civilization and Capitalism* (Baltimore: Johns Hopkins University Press, 1977), 11; Braudel, *Structures*, 114, 120; Moore, “Nature and the Transition from Feudalism to Capitalism.”
219. B.H. Slicher van Bath, *The Agrarian History of Western Europe, 500–1850 A.D.* (New York: St. Martin’s, 1963), 330; John C. Super, *Food, Conquest, and Colonization in Sixteenth–Century Spanish America* (Albuquerque: University of New Mexico Press, 1988), 20–22; Keith, *Conquest and Agrarian Change*, 66.
220. Assadourian, “The Colonial Economy,” 62.
221. Godoy, “The Evolution of Common–Field Agriculture in the Andes,” 405.
222. As in Brenner’s critique of the dependency and world–systems perspectives (“The Origins of Capitalism”).
223. Steve J. Stern, “New Direction in Andean Economic History: A Critical Dialogue with Carlos Sempat Assadourian,” *Latin American Perspectives* 12/1 (1985), 134.
224. Ramirez, “The ‘Dueno de Indios,’” 598; Paul Charney, *Indian Society in the Valley of Lima, Peru, 1532–1824* (Lanham: University Press of America, 2001), 17–18, 44.
225. Assadourian, “The Colonial Economy,” 60; Ramirez, *The World Turned Upside Down*, 73–74; Andrien, *Andean Worlds*, 81–82.
226. Assadourian, “The Colonial Economy,” 61.
227. Assadourian, “The Colonial Economy,” 62; Stern, *Peru’s Indian Peoples*, 109.
228. On the role of Potosi in shaping the colonial economy, see Assadourian, “The Colonial Economy”; Galeano, *Open Veins*, 43. On depopulation, see C.T. Smith, “Depopulation of the Central Andes in the sixteenth Century,” *Current Anthropology* 11 (1970): 453–463; Keith, *Conquest and Agrarian Change*, 42–47.
229. David E. Vassberg, “Concerning Pigs, the Pizarros, and the Agro–Pastoral Background of the Conquerors of Peru,” *Latin American Research Review* 13/3 (1978), 47; Charles C. Mann, “1491,” *The Atlantic Monthly* 289/3 (2002): 41–53.
230. Mining centers relied on European livestock for food, transportation, and power sources for mine hoists; sometimes they were even used in milling and the *patio* amalgamation process. Cattle offered not only meat but hides, made into sacks and pouches for carrying ore and mercury. They also supplied tallow for candles. Underground mining was impossible without these. Consumption of tallow in 1730s Zacatecas – considerably smaller than Potosi – was over 80 tons *a year*. See Semo, *History of Capitalism in Mexico*, 12; Crosby, *Columbian Exchange*, 86; Andrew Sluyter, “The Ecological Origins and Consequences of Cattle Ranching in Sixteenth–Century New Spain,” *Geographical Review* 86/2 (1996), 172

231. Crosby, *Columbian Exchange*, 98–99; J. H. Parry, *The Age of Reconnaissance* (New York: Mentor, 1963), 246.
232. See Lesley Bird Simpson, *Ibero–Americana 36: Exploitation of Land in Central Mexico in the Sixteenth Century* (Berkeley: Univ. of California Press, 1952); Francois Chevalier, *Land and Society in Colonial Mexico* (Berkeley: Univ. of California Press, 1963), 93–94; Wolf, *Sons of the Shaking Earth*; Sluyter, “The Ecological Origins and Consequences of Cattle Ranching.”
233. Ramirez, *The World Turned Upside Down*, 73–74; also W. George Lovell, “‘Heavy Shadows and Black Night’: Disease and Depopulation in Colonial Spanish America,” *Annals of the Association of American Geographers* 82 (1992), 437.
234. Lovell, “Disease and Depopulation,” 436; also Cole, *The Potosi Mita*, 28.
235. Stern, *Peru’s Indian Peoples*, 89, 88, 87; also Newson, “Indian Population Patterns,” 55.
236. Godoy, “The Evolution of Common–Field Agriculture in the Andes,” 406; Andrien, *Andean Worlds*, 86; Newson, “Indian Population Patterns,” 56. Many Indians also left the reducciones to reestablish “diffuse settlements of pre–Conquest pattern,” part and parcel of the resettlement strategy’s unraveling in the sixteenth century (Gade, 472).
237. Ruth Kearns Barber, *Indian Labor in the Spanish Colonies* (Albuquerque: University of New Mexico Press, 1932), 105; Cobb, *Potosi and Huancavelica*, 79–81; Cole, *The Potosi Mita*, 27–28; Bakewell, “Mining,” 231; Andrien, *Andean Worlds*, 76.
238. Cole, *The Potosi Mita*, 66n.
239. Andrien, *Andean Worlds*, 76.
240. Andrien, *Andean Worlds*, 62; Cole, *The Potosi Mita*, 37.
241. Cole, *The Potosi Mita*, 37.
242. Godoy, “The Evolution of Common–Field Agriculture in the Andes,” 406; also Karen Spalding, “Hacienda–Village Relations in Andean Society to 1830,” *Latin American Perspectives* 2/1 (1975), 111.
243. Ramirez, *The World Turned Upside Down*, 119.
244. Newson, “Indian Population Patterns,” 56; also Stern, *Peru’s Indian Peoples*, 151–152.
245. Dennis O. Flynn and Arturo Giraldez, “Cycles of Silver: Global Economic Unity through the Mid–Eighteenth Century,” *Journal of World History* 13 (2002): 404–405.
246. Bunker, *Underdeveloping the Amazon*.
247. Brading and Cross, “Colonial Silver Mining,” 573.
248. Jeffrey M. Paige, *Agrarian Revolution: Social Movements and Export Agriculture in the Underdeveloped World* (New York: Free Press, 1975), 14–15. Sugar processing could be on–site or proximate. The tendency toward economies of scale on the sugar frontier was just that: a tendency, although one that manifested with increasing force in the early modern era (see below). Ecology mattered, but it was not all that mattered.
249. Stuart B. Schwartz, *Sugar Plantations in the Formation of Brazilian Society* (Cambridge: Cambridge Univ. Press, 1985), 110–111.
250. A. Meredith John, “Plantation Slave Mortality in Trinidad,” *Population Studies* 42/2 (1988), 163.
251. Mintz, *Sweetness and Power*, 47.
252. Thompson, *Customs in Common*, 352–403.
253. Mintz, *Sweetness and Power*, 51; Richard S. Dunn, *Sugar and Slaves: The Rise of the Planter Class in the English West Indies* (New York: W.W. Norton, 1973), 190–191.

254. Frederic Mauro, "Toward an 'Intercontinental Model': European Overseas Expansion 1500–1800," *Economic History Review*, 2d series, 14/1 (1961), 4.
255. Crosby, *Ecological Imperialism*, 75; H. B. Johnson, "Portuguese Settlement, 1500–1580," in Leslie Bethell, editor, *Colonial Brazil* (Cambridge: Cambridge Univ. Press, 1987), 3; Masefield, "Crops and Livestock," 280.
256. Quoted in Perlin, *A Forest Journey*, 250
257. Charles R. Boxer, *The Portuguese Seaborne Empire 1415–1825* (New York: Alfred A. Knopf, 1969), 56.
258. Perlin, *A Forest Journey*, 252.
259. Shawn W. Miller, "Fuelwood in Colonial Brazil: The Economic Consequences of Fuel Depletion for the Bahian Reconcavo, 1549–1820," in Helen Wheatley, editor, *Agriculture, Resource Exploitation, and Environmental Change* (Brookfield, VT: Varorium/Ashgate, 1997), 135–159, 137.
260. Perlin, *A Forest Journey*, 409n; Bailey W. Diffie and George D. Winius, *The Foundations of the Portuguese Empire, 1415–1580* (Minneapolis: Univ. of Minnesota Press, 1977), 306–307; Schwartz, *Sugar Plantations*, 8; Robert Sabitini Lopez, "Market Expansion: The Case of Genoa," *Journal of Economic History* 24/4 (1964), 445–464.
261. Perlin, *A Forest Journey*, 252.
262. Jason W. Moore and Diana C. M. Gildea, "Forests and the Expansion of the World-Economy, 1350–1789," paper presented at the 95th annual meeting of the American Sociological Association, Washington, D.C., Aug. 12–16, 2000.
263. J.H. Galloway, *The Sugar Cane Industry: An Historical Geography from its origins to 1914* (Cambridge: Cambridge Univ. Press, 1989), 36.
264. Grove, *Green Imperialism*, 29.
265. Crosby, *Ecological Imperialism*, 78, emphasis added; Watson, 1983: 103.
266. Quoted in Perlin, *A Forest Journey*, 251; also John, 1988: 163.
267. Galloway, *The Sugar Cane Industry*, chapter 4; Schwartz, *Sugar Plantations*, 8.
268. This is the figure that Lockhart and Schwartz give for Brazil in the 1580s, and it seems reasonable for Madeira a century earlier and the Caribbean a century later (James Lockhart and Stuart B. Schwartz, *Early Latin America: A History of Colonial Spanish America and Brazil* [Cambridge: Cambridge Univ. Press, 1983], 206; see also David Watts, *The West Indies: Patterns of Development, Culture, and Environmental Change since 1492* [Cambridge: Cambridge Univ. Press, 1987], 366–368 and *passim*).
269. Stuart B. Schwartz, "Plantations and Peripheries, c. 1580–1750," in Leslie Bethell, editor, *Colonial Brazil* (Cambridge: Cambridge Univ. Press, 1987), 82–83; Robin Blackburn, *The Making of New World Slavery* (New York: Verso, 1997), 339.
270. Karl Marx, *Capital*, vol. II (New York: International Publishers, 1967), 468.
271. Blackburn, *The Making of New World Slavery*, 169.
272. Sauer, *Selected Essays*, 49–50.
273. Dunn, *Sugar and Slaves*; Lockhart and Schwartz, *Early Latin America*, 207; Richard Pares, *Merchants and Planters: Economic History Review Supplement No. 4* (Cambridge: Cambridge Univ. Press, 1960); Richard B. Sheridan, *Sugar and Slavery* (Baltimore, Johns Hopkins Univ. Press, 1973).
274. Wallerstein, *The Modern World-System I*, 121–122.
275. Braudel, *The Wheels of Commerce*, 192–194.
276. Pares, *Merchants and Planters*, 20.
277. Dean, *With Broad Axe and Firebrand*, 79–80.
278. Schwartz, "Plantations and Peripheries," 93; Antonio Barros de Castro, *The Colonial*

- Economy, Capitalist or Not? Some Empirical Data from Brazilian Sugar Plantations*, (Binghamton, NY: Fernand Braudel Center, 1977), 9.
279. Matthew Edel, "The Brazilian Sugar Cycle of the Seventeenth Century and the Rise of West Indies' Competition," *Caribbean Studies* 9/1 (1969), 42.
280. Schwartz, *Sugar Plantations*, 141.
281. Schwartz, *Sugar Plantations*, 302.
282. Galeano, *Open Veins*, 74.
283. Edel, "The Brazilian Sugar Cycle."
284. B.W. Higman, "The Sugar Revolution," *Economic History Review* 50/2 (2000): 213–236; Schwartz, *Sugar Plantations*, 8–10.
285. Blackburn, *The Making of New World Slavery*, 235.
286. Blackburn, *The Making of New World Slavery*, 169–170; Dunn, *Sugar and Slaves*, 64–65; on the relations among sharecropping, risk–minimization, and the world-economy, see Immanuel Wallerstein, "Comments on Stern's Critical Tests," *American Historical Review* 93 (1988): 873–885. On profitability, see J. R. Ward, "The Profitability of Sugar Planting in the British West Indies, 1650–1834," *Economic History Review* 31/2 (1978): 197–209.
287. Schwartz, *Sugar Plantations*, 302; Dunn, *Sugar and Slaves*, 67.
288. J.H. Galloway, "Tradition and Innovation in the American Sugar Industry, c.1500–1800: An Explanation," *Annals of the Association of American Geographers* 75/3 (1985), 343.
289. Ralph Davis, "English Foreign Trade, 1660–1700," *Economic History Review* 7/2 (1954), 152.
290. David Watts, "Ecological Responses to Ecosystem Shock in the Island Caribbean: The Aftermath of Columbus, 1492–1992," in Robin A. Butlin and Neil Roberts, editors, *Ecological Relations in Historical Times* (Oxford: Blackwell, 1995), 274.
291. Watts, *The West Indies*, 185–186.
292. Dunn, *Sugar and Slaves*, 26–27, 67.
293. Timothy Silver, *A New Face on the Countryside: Indians, Colonists, and Slaves in South Atlantic Forests, 1500–1800*. Cambridge: Cambridge Univ. Press, 1992), 117.
294. Watts, *The West Indies*, 186, 167.
295. Kirkpatrick Sale, *The Conquest of Paradise* (New York: Plume, 1990), 165.
296. Watts, *The West Indies*, 222.
297. Dunn, *Sugar and Slaves*, 203–204; N. Deerr, *The History of Sugar*. 2 vols. (London: Chapman and Hall, 1949–50), I, 166.
298. Schwartz, *Sugar Plantations*, 114; Watts, *The West Indies*, 397.
299. Pares, *Merchants and Planters*, 42.
300. Davis, *The Rise of the Atlantic Economies*, 254; also Dunn, *Sugar and Slaves*, 205; Ponting, *A Green History of the World*, 206.
301. Crosby, *The Columbian Exchange*, 90; Celso Furtado, *The Economic Growth of Brazil* (Berkeley: Univ. of California Press, 1963), 58–66; Stuart B. Schwartz, "Free labor in a Slave Economy: The *Lavadores de Cana* of Colonial Bahia," in Dauril Alden, editor, *The Colonial Roots of Modern Brazil* (Berkeley: Univ. of California Press, 1973), 167–168.
302. Watts, *The West Indies*, 222–223; Robert Carlyle Batie, "Why Sugar? Economic Cycles and the Changing of Staples on the English and French Antilles, 1624–1654," in Hilary Beckles and Verene Shepherd, editors, *Caribbean Slave Society and Economy* (New York: The New Press, 1991), 50.
303. Watts, *The West Indies*, 193, 198.
304. Dunn, *Sugar and Slaves*, 197; Schwartz, "Plantations and Peripheries," 93.

305. Watts, *The West Indies*, 297; also Deerr, *History of Sugar*, 166.
306. Watts, *The West Indies*, 402–405.
307. Galloway, “Tradition and Innovation,” 345.
308. Eric Williams, *Capitalism and Slavery* (London: Andre Deutsch, 1944), 113; see also Pares, *Merchants and Planters*, 41.
309. Charles Leslie, *A New and Exact Account of Jamaica, wherein The Ancient and Present State of that Colony, its Importance to Great Britain, Laws, Trade, Manners and Religion, together with the most remarkable and curious Animals, Plants, Trees etc. are described*, 3rd edition (Edinburgh: R. Fleming, 1740), 337 quoted in J. H. Galloway, “Tradition and Innovation,” 336.
310. Pares, *Merchants and Planters*, 41.
311. Williams, *Capitalism and Slavery*, 113–114.
312. Pares, *Merchants and Planters*, 39–40.
313. Blackburn, *The Making of New World Slavery*, 339.
314. Philip D. Curtin, “Epidemiology and the Slave Trade,” *Political Science Quarterly* 83/2 (1968): 190–216.
315. Richard B. Sheridan, “Africa and the Caribbean Slave Trade,” *American Historical Review* 77/1 (1972), 29; Dunn, *Sugar and Slaves*, 203.
316. Sheridan, “Africa and the Caribbean Slave Trade,” 29.
317. J.R. McNeill, “Ecology, Epidemics, and Empires: Environmental Change and the Geopolitics of Tropical America, 1600–1825,” *Environment and History* 5 (1999): 182, 175.
318. Where agro-ecology was not easily simplified (here I am thinking especially of wet rice agriculture’s complex labor process), slavery assumed a “task” rather than “gang” organization. See Judith A. Carney, *Black Rice: The African Origins of Rice Cultivation in the Americas* (Cambridge, MA: Harvard University Press, 2001). Had sugarcane been closer to rice in this respect, the rise of modern slavery would have played out much differently indeed.
319. McNeill, *Something New Under the Sun*, 358, 359.
320. See Arrighi, *The Long Twentieth Century: Money, Power, and the Origins of Our Times* (New York: Verso, 1994); Christopher Chase-Dunn and Thomas D. Hall, *Rise and Demise: Comparing World-Systems* (Boulder, CO: Westview Press, 1997).
321. Brenner, “The Low Countries in the Transition to Capitalism.”
322. Harold Innis, *Essays in Canadian Economic History* (Toronto: University of Toronto Press, 1956); Cronon, *Nature’s Metropolis*.