

Madeira, Sugar, & the Conquest of Nature in the ‘First’ Sixteenth Century

Part II: From Regional Crisis to Commodity Frontier, 1506-1530¹

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At the rosy dawn of sixteenth century capitalism, few places in this “vast but weak” world-economy were more pivotal than Madeira. A small island in the middle of the Atlantic Ocean, Madeira in 1500 was the greatest producer of early capitalism’s most important cash crop, sugar. Every year between 1505 and 1509, some 2,000 tons of sugar flowed from Funchal, Madeira’s capital, to Lisbon, Antwerp, Genoa, and many places beyond. Two decades later, the island’s sugar complex had collapsed. In the second of two essays in Review, I illustrate how the socio-ecological regime that enabled Madeira’s sugar revolution between 1450 and 1500 ensured the rapid decline of production after 1506. As we explored in Part I, this regime had everything to do with the forest. No cash crop devoured the forest so quickly as sugar. If dwindling fuel supplies were sugar’s greatest vulnerability, the sources of sugar’s boom and bust on Madeira were irreducibly world-historical and multi-layered. In Part II, I trace the connections between earth-moving and the broader structures of capital and empire, above all the socio-ecological architectures of the world market and the Portuguese Empire in Braudel’s “first” sixteenth century (c. 1450-1557 I begin by elaborating the relations between deforestation, soil fertility, and faltering labor productivity in agriculture as decisive to sugar’s rapid decline. Far from a narrowly regional phenomenon, this rapid decline was not only caused, but indeed necessitated, by the rise of capitalism as world-ecology – a civilization that joins the endless conquest of nature and the endless accumulation of capital in dialectical unity. In sum, regional socio-ecological crises were not merely resolved through commodity-centered frontier movements; they were also created by them.

At the rosy dawn of sixteenth century capitalism, few places in this “vast but weak” world-economy² were more pivotal than Madeira. A small island in the middle of the Atlantic Ocean, Madeira in 1500 was the greatest producer of early capitalism’s most important cash crop, sugar. Every year between 1505 and 1509, some 2,000 tons of sugar flowed from Funchal, Madeira’s capital, to Lisbon, Antwerp, Genoa, and many places beyond. Two decades later, the island’s sugar complex had collapsed. Production in 1525 was barely 20 percent of the 1506 peak.

What happened? In the second of two essays in Review, I illustrate how the socio-ecological regime that enabled Madeira’s sugar revolution between 1450 and 1500 ensured the rapid decline of production after 1506. As we explored in Part I (Moore, 2009a), this regime had everything to do with the forest. No cash crop devoured the

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² The phrase is Braudel’s (1961).

forest so quickly as sugar. The island-wide disturbance of forest ecosystems was sufficiently serious that the first of several major extinctions of endemic molluscs occurred in the early sixteenth century, the result of “*rapid and large-scale change in the habitat, from woodland to grassland*” (Goodfriend, Cameron, and Cook, 1994: 318, emphasis added).

If dwindling fuel supplies were sugar’s greatest vulnerability, the sources of sugar’s boom and bust on Madeira were irreducibly world-historical and multi-layered. Where Part I focused on landscape transformations, in Part II I trace the connections between earth-moving and the broader structures of capital and empire, above all the socio-ecological architectures of the world market and the Portuguese Empire in Braudel’s (1953) “first” sixteenth century (c. 1450-1557). I begin by elaborating the relations between deforestation, soil fertility, and faltering labor productivity in agriculture as decisive to sugar’s rapid decline. Far from a narrowly regional phenomenon, this rapid decline was not only caused, but indeed necessitated, by the rise of capitalism as world-ecology – a civilization that joins the endless conquest of nature and the endless accumulation in dialectical unity. Early capitalism, forged through successive commodity frontiers (sugar especially), was a structure of power committed to regional crisis as a way of life. In sum, regional socio-ecological crises were not merely resolved by commodity-centered frontier movements; they were also created by them.

HISTORICAL CAPITALISM AND REGIONAL CRISIS: FROM WORLD-ECONOMY TO WORLD-ECOLOGY

In what sense can we speak meaningfully of a “crisis” of Madeira’s sugar complex? The salient facts are these. The sugar economy declined rapidly after 1510. From an average of 1900 tons in 1505-09, annual output declined to 1073 tons in 1515-19, to 835 tons in 1520-24, to 549 tons in 1525-29, to barely 300 tons in the 1530s. Production, peaking at 2480 tons in 1506, fell to 1180 tons in 1516, and just 467 tons a decade later. This collapse occurred in the midst of an improving world market for Madeira’s producers. The real price fetched for Madeira’s best grades of sugar increased by one-quarter between 1515 and 1517, and by fifty percent between 1515 and 1520, a price level that held more-or-less steady over the following decade (calculated from Pereira, 1969d; also Schwartz, 1985). New competitors emerged only after 1530. São Tomé, Madeira’s eventual successor, struggled to export just 80 tons of low-grade sugar in 1529. Meanwhile, as we learned in Part I, the island’s forests had receded sharply prior to the post-1506 conjuncture, and Madeira’s slave population grew considerably after 1506. Although there were a succession of short-lived sugar revivals over the next century (Mauro, 1983), there would be no more sugar revolutions. By 1546, Magalhães reports, “it is already written that ‘most people on the island live by the vines’” (2009: 161). After the sixteenth century, most people knew Madeira for wine, not sweets.

We will presently explore Madeira’s crisis in some detail. Before doing so, however, let me offer a consideration of this oft-used and undertheorized term, crisis. There were two novel, and specifically modern, features of this regional crisis in the decades after 1506. First, the pace of boom and bust on Madeira was unlike anything known in medieval Europe. Regional booms in feudal Europe unfolded through the necessarily sluggish movement of settler frontiers (Bartlett, 1993; Lewis, 1958; Moore 2003b, 2007). Commerce followed people in the Middle Ages. After 1450, people followed the commodity. By the long sixteenth century, medieval Europe’s settler frontiers rapidly gave way to commodity frontiers. Urban-based capital was stymied

within most of the European heartland during the first sixteenth century, thanks to the resistance of peasantries, urban guilds, and a patchwork of territorial and juridical formations. There were exceptions in this initial century of capitalist transition, especially in Central Europe's mining zones (Moore, 2007: chapter two). On balance, however, urban-based capital looked abroad for new landscapes where the "original sources of all wealth" (land and labor) could be mobilized in servitude to the commodity form (Marx, 1976: 636-638). What leant this process of commodification a new urgency was the doubly competitive structure of the emergent capitalist order – inter-state and inter-capitalist competition.

This doubly competitive structure ensured that the rapid exhaustion of land and labor in the new commodity frontiers and the rapid expansion of Europe's territorial claims were mutually constituting. The second novel feature of regional crisis was therefore the global ecological fix. In other words, the modern conquest of time and the modern conquest of space were dialectically joined. Regional crises, after 1450, were those turning points through which a leading commodity complex yielded its systemic primacy. Sugar offers an especially clear case of this spatio-temporal movement. Madeira would give way to São Tomé, and then to Brazil and the Caribbean, over the next three centuries. It was not an all-or-nothing affair; some sugar was produced on Madeira throughout the early modern era. Rather, we are talking about the world-historical movement through which new regional centers rise to (and then fall from) the commanding heights of the commodity sector in question. Sugar offers a paradigm instance of this process, but it was by no means alone.

I have drawn attention to commodity production and exchange, and capitalism is usually discussed in such terms. But this is only part of the picture. My preference is to situate commodification within the totality of capitalism's conditions of reproduction, a move that puts the messy relations between humans and the rest of nature front and center. In place of a Cartesian paradigm that sees "social" forces imposing their will upon an exogenous nature, I propose that we view the production of nature, the pursuit of power, and the accumulation of capital as an organic whole. This is the perspective of capitalism as *world-ecology* (Moore 2003c, 2009a, 2009b, 2010a, 2010b, 2010c, 2011a, 2011b). Rather than blur distinctions within the organic whole, the world-ecological perspective refrains from the *a priori* designation of the "social" and the "environmental" and opens up the analysis of all forms of human experience to the interplay of human and biophysical natures. While this point has been powerfully argued on the terrain of social theory (e.g. Braun and Castree, 1998), the present argument is a brief for rethinking the great categories of world-historical social change – imperialism, commodification, social revolutions, and so forth – as socio-ecological projects and processes.

My point of departure is therefore the conditions of reproduction (the web of life) within which the generalization of commodity production and exchange takes place. For this reason I emphasize a theory of commodity frontiers that goes beyond the geographical extension of commodity relations (Moore, 2000b, 2003a, 2007; *pave* Cronon, 1991). Commodity frontiers were so extraordinarily effective in the rise of capitalism because the capitalization of socio-ecological relations was joined to the appropriation of nature's "free gifts" (Marx, 1967, III: 745). On these frontiers, a relatively small volume of capital, backed by territorial power, could appropriate a very large basket of nature's gifts. This explains the apparent paradox of sugar frontiers especially, where precocious forms of technological and institutional innovation took root in distant and seemingly "backward" regions (Mintz, 1985; Sheridan, 1968).

This epochal innovation was distinctive, but not limited, to sugar frontiers. Across

the diversity of early modern commodity frontiers – timber, metals, fisheries, and cereals, from Brazil to the Baltic – a common pattern obtained. The defining feature was not the absolute penetration of commodity relations, but the maximization of labor productivity through the appropriation of biophysical and human natures. This marked a radical reversal of feudalism's rules of reproduction. If *land productivity* governed the conditions for prosperity and poverty in feudal Europe, *labor productivity* was increasingly decisive in the capitalist world-ecology. Soil exhaustion and resource depletion were fundamental contradictions of the feudal order; under capitalism, these were irritations, signified by regional crises. These crises were quickly overcome through successive global ecological fixes, pioneered by the new commodity frontiers. Once labor productivity faltered in any given commodity complex, capital flowed elsewhere. Even in the first sixteenth century, we can glimpse the formation of Marx's law of value, through which labor productivity emerged as the metric of value for the modern world-system (Moore, 2009b, 2010c, 2011a, 2011b).

SUGAR, LABOR, AND THE FOREST: THE QUESTION OF SOIL EXHAUSTION

Madeira's ecological origin myth tells of a great fire that accompanied the earliest moments of settlement (Moore, 2009a). The "accidental" fire, for which human action was not responsible, was said to have lasted seven years, removing large parts of the island's forest cover. The resulting "destruction of Wood hath caused since a great want," Samuel Purchas clarified in the 1620s (1625: 6). As we saw in Part I, the "destruction of Wood" on Madeira was not accidental at all. It was a destruction propelled by a fuel-hungry sugar frontier that removed half the island's accessible forests by the early years of the sixteenth century.

Such myths are so powerful because they have a way of shaping what we see, and what we do not see. In the case of Madeira's origin myth, human action was cleansed from the story of forest destruction. This story meets up with an even grander, if more subtle, myth, operative in the historiography of sugar.

For much of the past two centuries, soil exhaustion has been regarded as a defining problem of the modern sugar complex. "Neither skill, nor capital nor abundance of labour have ever been found able to compete, in tropical cultivation, with the advantage of a new and fertile soil," Herman Merivale told Oxford audiences in 1839-41 (1841: 298; also, *inter alia*, Galt, 1833; Williams, 1944; Dunn, 1972; Watts, 1987, Monzote, 2008). Soil exhaustion has certainly been an important reality. But there is also an important sense in which its significance has been misrecognized, detached from labor productivity as the decisive element in competitive fitness. If soil exhaustion was a powerful force in the modern sugar commodity frontier, what kind of force was it? Was it an external barrier, as the historiography suggests, or was it rather endogenous, decisively mediated by the law of value? Capitalism cares little about soil fertility in itself. Its central concern is the productivity of labor in the service of commodity production.

At stake is the civilizational political ecology within which soil exhaustion operates – clearly an enduring problem for human civilization across the millennia (Montgomery, 2007). The historiographical emphasis on soil exhaustion establishes biophysical factors as exogenous, but this is true only in a supremely abstract way. Like Madeira's ecological origin myth, the soil exhaustion narrative tends to locate the source of modernity's problems in an exogenous and ahistorical nature. The latter, to be sure, acknowledges that human agents create problems with a nature that exists "out there," but elides the specific socio-ecological content of labor

mobilization in historical capitalism. Soil fertility and exhaustion are in fact eminently historical relations internal to the capitalist mode of production. Far from washing away the “objective propert[ies] of the soil,” such a reading reminds us that “fertility is not so natural a quality as might be thought; it is closely bound up with the social relations of the time” (Marx, 1967, III: 650; Marx, 1973: 141). The real socio-ecological barrier of capitalist production, as Marx might say, is capital itself (1967, III: 250).

The alternative is an optic that privileges labor productivity and thus the internalization of human nature within the capitalist world-ecology. For this reason, I have always appreciated Wallerstein’s underappreciated formulation of “ecological exhaustion” (1980: 162). In this perspective, the mobilization and exhaustion of labor and land, human- and extra-human nature, are dialectically bound (Wallerstein, 1974: 44, 89; Wallerstein, 1980: 132-133, 162n; Moore, 2007; Marx, 1976: 636-38). For Madeira in the first sixteenth century, it is probably best to situate such exhaustion within the broader ensemble of socio-ecological relations governing the island, and those obtaining within the Portuguese empire. This recasts the crucial variable as one of the relative profitability of the ecological regime, not than the apparent “bigness” of this or that moment of environmental change – soil exhaustion, deforestation, pest invasions, and so forth.

On Madeira after 1506, the chief problem was not soil exhaustion so much as it was the exhaustion of Madeira’s ecological regime. This regime had sustained rising labor productivity during the sugar boom. There were two major pillars of high labor productivity, cheap inputs from the forest, and fertile soil. Both pillars eroded significantly after 1506, issuing declining productivity and aggregate production.

While canefields diffused across the southern half of the island in the half-century after 1450, the sugarmills (*engenhos*) did not. The *engenhos* remained geographically clustered around Funchal (Vieira, 2004: 57). There was consequently pressure to overexploit nearby forests; the hillsides surrounding Funchal were picked clean in the early sixteenth century (Vieira, 2009: 12). In 1519, the construction of new lime kilns – producing construction material – was banned on the grounds that they threatened “great loss” to the island’s sugar producers (Magalhães, 2009: 161). By 1520, Funchal’s residents were looking to Machico, in the northeast, for firewood and other timber “because it no longer remained in the [municipal] council’s area” (*ibid.*).

Demand for fuelwood was consequently not generalized equally across the 30,000 hectares or so of commercially accessible forest. *Engenhos* were voracious consumers of fuel, consuming 60 kilograms of wood for every kilogram of sugar (Moore, 2009a). As mills clustered geographically, they exhausted the woodlands nearby and close to waterways, and firewood had to be carted in from farther and farther away. There was consequently an inexorable trend towards declining labor productivity for the most significant raw material (after cane) in the production process. True, Madeira is small, but carting was an expensive proposition, all the more so given the island’s steep topography. More and more labor was necessary to secure the same amount of energy.

Deforestation was doubly problematic for Madeira’s sugar complex. It wasn’t simply that the forests supplied fuel for the boiling houses. Cane farmers depended on forest clearance, by means of organized (if not always contained) burns, to sustain labor productivity. Cleared forest served two functions. First, the creation of arable land from the forest greatly enriched the soil, thanks to fertility bestowed upon it by “the black ash of the forest” (Bryans, 1959: 23; also Albuquerque and Vieira, 1988: 22, 27; Africanus, 1600: 56). The burned-over forest provided more than black ash.

There was also a “yield honeymoon” provided by newly-cleared soils biologically unfamiliar with sugarcane (Dark and Gent, 2001). At first, new canefields enjoyed a respite from the greatest threats to labor productivity – weeds and pests. Early accounts of Madeira’s colonization reported extraordinary yields, as high as 70:1 (Cadamosto, 1455: 9).

Madeira’s honeymoon with sugar was over by the early sixteenth century. Leo Africanus, writing sometime between 1518 and 1526, drew a sharp contrast between the fertility of Madeira’s early years and the decline of sugar. The sugar harvest “now... cometh not to one halfe of that [earlier] reckoning” (1600: 56). This sort of observation recurred throughout the early modern sugar frontier, in Brazil, Barbados, and Jamaica, as we saw in Part I (e.g. Lesley, 1740: 337).

Problems with soil fertility persisted. More than a century and a half later, the English merchant Ovington observed that:

The Fertility of this Island is much abated from what it was in the Time of its first Plantation; and the continual breaking up of the Ground has, in many Places, impoverished its Productions; so that they are obliged to let it lie fallow for three or four Years: After which Time, if there springs-up no Bloom, they conclude it is quite barren (1689: 563).

Monoculture achieved short-run gains by simplifying the land (the object of labor) as a means of maximizing labor productivity. Over the middle-run of three decades, this monocultural strategy was progressively self-limiting. As the forest receded, it became difficult to expand arable land through renewed forest clearance. This clearance, as we have seen, attenuated monoculture’s encouragement of weed and pest problems. The result was an upward spiral of pestilence. Weeds in early modern plantation agriculture enjoyed a dramatic, non-linear growth curve (Watts 1985), and were probably the most powerful vector of soil exhaustion. They also proved a formidable drag on labor productivity. In eighteenth-century Brazil, weeding consumed as much labor as the grueling tasks of cutting and carting cane, combined (Schwartz, 1985: 142; for eighteenth century Barbados, see Roberts, 2006).

Sugarcane created yet other biological competitors. In 1502 caterpillars ravaged canefields across the island. It was the first of many pest invasions (Koebel, 1909: 128; Mauro, 1983: 207; Duncan, 1972: 32; Rau, 1964: 5). Mauro is prepared to go still further. The caterpillar invasions that began in earnest after 1502 “attacked [not only] the canes, [but also] the manpower” (1983: 206). Nor were caterpillars the only pests. There was also the “struggle against rats, against which the slaves were deployed with all their diligence” (Mauro, 1983: 207). Such multi-form pestilence became a recurrent feature of the sugar commodity frontier. In São Tomé just two decades later in the 1520s – and just three decades after sugar cultivation commenced on the island – so-called ship rats, unintentionally imported from Europe, had “mightily impaired the growth of this commodity,” for a time cutting export volume by 85 percent (Africanus 1600: 53; Dutton, 1994: 928).

These countervailing forces created by King Sugar “impoverish[ed]... the soils” on Madeira by the early sixteenth century, “inevitably reduc[ing]... productivity capacity” (Pereira, 1969d: 158, 220; also Pereira, 1969b: 484, 462). The most dramatic expressions of this trend were found in the captaincy of Funchal, where sugar cultivation began on the island. In contrast, Machico to the northeast declined much more slowly, a difference that Albuquerque and Vieira explain in terms of the relative soil fertility (1988: 29).

SUGAR, SLAVERY, AND LABOR PRODUCTIVITY

“Most of the Islands inhabited by the Portugals, especially those of Saint Thomas and Madera, besides the Portugals themselves, containe a great multitude of Negro-slaves, brought thither out of Congo and Angola, who till the earth, water the sugar-canes, and serve both in the cities, and in the countrie.”

– Leo Africanus, c.1518-26 (1600: 417)

To the paradox of rising prices and falling production, we can add the paradox of increasing slave imports and decreasing sugar output. The evidence is not what one would wish. While there is some evidence on patterns of slaveholding (Vieira, 1996), we have neither good figures on annual slave arrivals nor on slave mortality.

We do, however, have reliable estimates of Madeira’s slave imports during its sugar revolution and subsequent crisis. Even working from a highly conservative reckoning of slave population – one that overstates slave productivity – the result is a curious sort of Kuznets-curve, one characterized by sharply rising, then rapidly declining, labor productivity. It is precisely what one would expect from a sugar revolution capitalizing on a yield honeymoon, followed by a strong socio-ecological pushback. As fields were exhausted or plagued with pests and weeds, as woodland receded, ever more labor was required to maintain output.

How much labor did it take to cultivate and process 1,000-2,000 tons of sugar? I begin with Barrett and Schwartz’s estimate of slave productivity for sixteenth century Brazil (1975: 542) – the middle range of which is .33 tons per labor-year (also see Moore, 2007: 260; Blackburn, 1997: 205). With this reckoning, the 1680 tons Madeira produced in 1498 required the full-time labor of 5,040 unfree cultivators and technicians.³ This is a generous estimate for slave productivity, more than 25 percent higher than the prevailing average in 1680 Barbados.⁴ Of course, Madeira was not a slave colony on the model of seventeenth century Barbados (Vieira, 1996, 2004). Vieira tends to minimize the role of slavery during Madeira’s sugar cycle, but it is difficult to see how the island could have produced so much sugar otherwise (Greenfield, 1977). Blackburn thinks that some 2,000 slaves worked on the island at the end of the fifteenth century, “mostly” in sugar (1997: 109).⁵

Was the supply of slaves sufficient to sustain sugar’s rising labor demands?

³ There are two principal ways to measure slave productivity. One is at the level of the individual, the other at the level of the social economy. When Deerr (1949: 101) puts slave productivity for seventeenth century Brazil at 60 arrobas (1940.4 lbs), we are looking at the productivity within the cultivation process itself, hived off from processing, and also (no less crucially) from transport and distribution (also Taylor, 1970). The measure of slave productivity that I am using seeks to illuminate Madeira’s social ecology as a whole.

⁴ Whether or not labor productivity was substantially higher in the West Indies remains an open question. Looking at Antigua, St. Kitts, Montserrat, and Nevis in the 1770s – which together produced 21,158 tons (as much as Brazil in 1700) – Deerr’s figures indicate a range of labor productivity between .198 tons/slave (Antigua) and .39 tons/slave (St. Kitts), with an average productivity of .26 tons/slave (for 82,270 slaves) (all calculated from Deerr, 1949: 174). This was roughly the same in Barbados c. 1680. The island produced about 10,000 tons of sugar (1683) with 38,782 slaves (1680), which yields a level of productivity *exactly* the same, .26 tons/slave (calculated from, respectively, Dunn, 1972: 203, and Galloway, 1989: 81). Schomburgck, drawing on contemporary reports, thinks the number of slaves was significantly higher, 46,602 in 1683-84 (1848: 82), which would have depressed labor productivity still further.

⁵ An additional 1500 workers cut and hauled wood. This is a deliberate underestimate. I’ve calculated that one woodcutter was necessary for every 1.62 tons of sugar. I have calculated on the basis of the new arroba (32.34 lbs), from the number of woodcutters in Bahia in the 1750s (4000), and the region’s sugar output in 1758 (400,000 arrobas) (Miller, 1994: 184; Schwartz, 1985: xxiii, 423).

Between 1450 and 1500, 17,500 African slaves were shipped into the northern Atlantic islands (Rawley and Behrendt, 2005: 20).⁶ The figure excludes São Tomé and Europe. If we assume that 10,000 of these workers (60 percent) were destined for Madeira, and that most of them (90 percent) arrived after 1470, this put annual imports between 1470 and 1500 at 300. Klein is more cautious, estimating annual slave arrivals at 200 in 1476-1525 (2004: 203). Given sugar's labor demands, this estimate strikes me as a theoretical minimum.

At this point, we are again pushed back to a quantitative reckoning. We can make three assumptions about the slave population on Madeira, all of which minimize declining labor productivity: 1) very modest annual slave imports (200); 2) very high slave mortality (five percent);⁷ and 3) the complete absence of slaves in 1475. Even with these caveats, slave population increased very fast, to 2,054 by 1488, and to 3,000 by 1500. Productivity, through 1509, increased even faster, moving from .37 tons/slave to .57 tons in the two decades after 1489. Thereafter, as we see in Table I, the trend is sharply downward. In the two decades after 1509, labor productivity fell from .57 tons to .15 tons/slave.

TABLE I,
SUGAR, SLAVERY, AND LABOR PRODUCTIVITY ON MADEIRA, 1475-1529

	Slave Population	Sugar Production	Productivity (annual)
1489	2151	800 tons	.37 tons/slave
1499	2892	1200 tons	.41 tons/slave
1504	3142	1500 tons	.47 tons/slave
1509	3337	1900 tons	.57 tons/slave
1519	3602	1073 tons	.3 tons/slave
1524	3692	835 tons	.23 tons/slave
1529	3762	549 tons	.15 tons/slave

Sources: Klein, 2004; Moore, 2007; Pereira, 1969d.

More and more labor was required to extract wealth from external nature. The foregoing estimates bear only an indirect relation to the reality they seek to illuminate. Naturally, many unfree workers were involved in other activities, including the vineyards that began to supplant canefields in a big way after 1520; free labor was mobilized widely; and there were many small cultivators, with just one or two slaves. And yet, a growing number of slaves entered Madeira after 1475. The trend was towards more, not fewer, slave arrivals: in the 1550s, some 300 slaves landed in Funchal every year (Mauro, 1983: 206). With so many slaves arriving, how was it that a "labor shortage" afflicted the island, dating from the 1520s (Vieira, 2004: 48)? At

⁶ Building on Elbl's estimates (1997) and Curtin's geographical distributions (1969).

⁷ Viewed from the *longue durée* of the sugar frontier, slave mortality was rarely higher than five percent, with a few gruesome exceptions to be found in the eighteenth century Caribbean – abstracting, of course, the horrific mortality of the Middle Passage itself (Moore, 2007: Chapters Five and Six).

least 3,700 slaves on lived on Madeira by 1525, when sugar output was less than one-quarter its 1506 peak. True, the economy was reorienting towards vines, and estate formation in viniculture could be labor intensive. Does this explain a situation of labor scarcity? Perhaps in part. At the same time, is it not more plausible to account for this tightening labor market primarily in terms of the political ecology of declining labor productivity in the sugar sector? In the conjuncture of 1510-30, planters were seeking to maintain output in an agro-ecological environment of dwindling fuel resources and declining soil fertility, and in a market environment of rising sugar prices.

LABOR, SOIL, AND THE FOREST: ACCOUNTING FOR MADEIRA'S RAPID DECLINE

The squeeze on soil fertility and labor are compelling factors in accounting for Madeira's decline. But I don't think they explain the *speed* of that decline. Viewed in comparative perspective, declining soil fertility – barring catastrophic episodes of soil erosion – was unlikely to issue such a sharp decline. There were mechanisms to counteract the tendency towards declining soil productivity. Madeira's soils were already manured (Galloway, 1989), and more could be brought in; pest invasions could be severe, but tended to produce sharp and episodic production shortfalls; the evolution of weeds was a major problem, but one that could be addressed by putting more men on the job.

The exhaustion of the forest was only thing that could not be fixed. Fuelwood demands were simply too great, the island too small, the economics of transport too unfavorable. Recall that amongst the motivations of Madeira's initial colonization was the quest for timber, and that sixteenth-century Portugal was wracked by growing timber supply problems (Devy-Vareta, 1986; Pinto, Aguiar, and Partidário, 2010). Labor, capital, food, livestock – all could be shipped into Madeira as needed, so long as the economics of the situation allowed. Fuel was the one item that could not be easily secured from abroad.

The world market remained quite favorable for Madeira's sugar. The paradox is that Madeira's boom played out in a period of falling sugar prices, while its crisis unfolded in an era of rising real prices. During the island's boom, sugar prices declined from an average of 725 *reais* per arroba in 1469 to 475 *reais* in 1496 (Rau, 1964: 9; also Vieira, 2004: 62). In England, sugar's price declined 75 percent – and in France by a little more – over the course of the fifteenth century (Edel, 1969: 26; Taylor, 1978: 14). The nadir was the depression of 1497-99, a genuine overproduction crisis. But it was short-lived. Recovery and thence renewed expansion was quick (Albuquerque and Vieira, 1988). How was this possible? The sugar revolution's yield honeymoon depressed the costs of production faster than market prices fell.

After 1500, Madeira's sugar enjoyed stable, even rising, prices (Pereira, 1969d; also Garfield, 1992: 65). Measured in gold, the price of sugar increased 460 percent on the London market between 1501 and 1540, although in real terms not so sharply (Simonsen, 1957: 143). Demand for the island's sugar was also consistently high in Antwerp, where prices were rising through the first half of the sixteenth century (Harreld, 2003: 151). In contrast to the spice trade, sugar enjoyed steadily rising real prices in the sixteenth century, increasing .44 percent per annum until 1550, and .53 percent over the next half-century (O'Rourke and Williamson, 2002: 446-448). All of which indicates that the rising price of sugar was no artifact of the Price Revolution, with its origins in the European silver mining boom of the 1460s, accelerating

strongly after 1520 (Braudel and Spooner, 1967; Munro, 2003; Moore, 2007: Chapter Two).

If São Tomé or Brazil had been the culprit of this decline, we would expect to see major exports from these zones towards the beginning, not the end, of Madeira's crisis. São Tomé, however, became a major producer only in the 1540s. In 1529, São Tomé exported just 80 tons a year, although this would increase thirty-fold by 1555 (Hodges and Newitt, 1988: 20; Garfield, 1992: 72). In any event, Madeira and São Tomé did not produce the same grade of sugar. Madeira's sugar was prized for its high quality, quality that was won by additional phases of fuel-intensive processing (Vieira, 2004; Pereira, 1969d). In contrast, São Tomé's competitive edge was quantity, not quality; its sugar was of notoriously low quality (Garfield, 1992: 64-65; Harreld, 2003: 152-153). As for Brazil, its output matched São Tomé's by the 1560s, reaching 2,654 tons annually in that decade (Simonsen, 1957: 172-173; Hodges and Newitt, 1988: 20), but this was a half-century removed from Madeira's crisis.

MADEIRA'S CRISIS IN THE EXHAUSTION OF PORTUGAL'S FIRST IMPERIAL ECOLOGICAL REGIME

Madeira's crisis was hardly isolated within the Portuguese Empire. For Pereira, the half-century between 1475 and 1525 was one of an "urgent" imperialism characterized by the Empire's "excessive demand" for natural resources. At the beginning of this era,

it was possible to find the necessary ingredients for global expansion: men, skills, motivation and strategic raw materials. The activation of the resources of the realm and the islands continued to be pursued, with a paradoxical exhaustion of these same resources in all spaces. Until the end of the period, no serious ruptures were to be noticed, whether in demographic terms, in the renewal of the labor force, or in terms of raw materials... [By the 1520s, however,] the first signs of the exhaustion of strategic raw materials began to appear, particularly wood and metals, as well as the lengthy and difficult processes of renewal and extraction (2006: 10, 12, emphasis added).

A precocious "monarchical capitalism" that pioneered the capitalist Atlantic (Dias, 1967; Wallerstein, 1974), the Portuguese Empire was also at the cutting edge of world-ecological change. Elsewhere in Europe, the demographic contraction of the long fourteenth century had given the Continent's forests some breathing room (Williams, 2003). Not so in Portugal. The second half of the fifteenth century inaugurated an era of "intense deforestation" in Portugal, characterized by escalating conflicts between agro-pastoral, peasant, urban, and manufacturing interests (Pinto, Aguiar, and Partidário, 2010: 20; Devy-Vareta, 1986, 2007). As a result, Portugal's forest woes materialized a century before those of western Europe, and decades before Spain's (Moore, 2010a, 2010b). Just as deforestation on Madeira materialized several waves of species extinction, the new wave of forest appropriations registered the extinction of the red squirrel (*Sciurus vulgaris*) within Portugal by the late sixteenth century (Goodfriend, et al., 1994; Mathias and Gurnell, 1998).

Within Portugal, fuelwood was increasingly expensive, and this influenced the geography of sugar refining within Europe. While the initial processing of cane had to take place on Madeira, further refining was increasingly relocated beyond the island, first to Lisbon, and then to Antwerp. By 1496, one-quarter to one-third of Madeira's sugar was marketed by Flemish capital, a volume of sugar six times greater

than Portugal's net sugar inflow (Furtado, 1963: 8; Birmingham, 2000: 13; Taylor, 1978: 16). Fuel-intensive clarification and refinement began to concentrate in northwestern Europe. The recentering of sugar refining indicates a situation of rising fuel costs not only on Madeira, but also in Portugal, relative to northwestern Europe. While the maritime Low Countries were also sparsely forested, urban manufacturers such as sugar refiners could access abundant peat (de Zeeuw, 1978).

Alas, Lisbon enjoyed neither coal nor peat. In 1559, the Crown prohibited sugar refining in Lisbon because its fuel demands threatened the supply of shipbuilding timber (Mauro, 1983: 272). The 1559 prohibition on sugar refining was issued at the very moment when the Crown was taking other measures to preserve forest resources, when Madeira's sugar complex was but a shadow of its former self, and when the Mediterranean world as a whole was in the midst of a "timber crisis" (Braudel, 1972: 143; also Cipolla, 1976: 228-230). While sugar did not demand high-quality timber, in Portugal as throughout early modern Europe, such timber was nevertheless widely used as fuelwood. The political ecology of Europe's forests was dominated by an endemic (and chaotic!) "battle for wood" (Devy-Vareta, 1986; Goodman, 1997, 1998; Moore, 2007, 2010a, 2010b; Westermann, 1996). In 1565 the Portuguese Crown imposed a "Law of Trees" and would initiate various tree planting schemes over the next few decades (Devy-Vareta, 1986). Barros reports that "mentions of timber shortages [began to appear]... in Lisbon by the end of the sixteenth century" (2006), a situation that persisted until well into the 18th century ((Mendes, 2004: 83; also Pinto, Aguiar, and Partidário, 2010).

Signs of Braudel's timber crisis were apparent across Mediterranean Europe. Madeira's crisis was surely one contributing factor in the exhaustion of Portugal's first imperial ecological regime by the 1520s. If Portugal ran into trouble somewhat earlier than the rest of this "macro-Mediterranean" (Mauro, 1992: 103), is this not explicable by its head start in overseas expansion? Not just Portuguese, but also Spanish shipbuilding was "in a state of crisis from the 1560s on" (Phillips, 1986: 22; also Moore, 2010a). Philip III (Portugal's Felipe II) (r. 1598-1621) would be warned by a senior naval commander that "those lands [within Portugal] that produce wood *should be guarded like the Potosí hills*" (quoted in Barros, 2005: 11, emphasis added).

This timber crisis turned on the capacity of the European Mediterranean's forest regime to sustain a competitive position relative to the North Atlantic. This was about more than forests, to be sure, but cheap and reliable flows of forest products were central to the era's competitive struggles. It is also true that the region's forests did not disappear. Even in the famous case of the Venetian Republic, absolute scarcities of forest products rarely occurred (Appuhn, 2009). The crucial geohistorical shift was found in the ways that the global fixes of the capitalist world-ecology were implicated in the rise of the "capitalist North Atlantic" and the decline of the "global" Mediterranean (Moore, 2010a, 2010b; Braudel, 1972). The relocation of shipbuilding centers and leading commodity frontiers – such as sugar planting – were dialectically bound. On the one hand, the Mediterranean crisis allowed northwestern Europeans to capture not only the high-profit activities of the sugar complex (refining and marketing), but also the high-profit lines of shipping and shipbuilding. Whereas Southern Europe's share of European fleet capacity was 40 percent in 1500, by 1780 it had fallen to 15 percent (van Zanden and Hørlings, 1999: 36; Unger, 1992: 260-261). Portugal would end up building ships in Bahia (Brazil) and Goa (India) by the seventeenth century (Morton, 1978; Özveren, 2000).

MADEIRA IN THE RISE OF THE CAPITALIST WORLD-ECOLOGY

It is dangerous to read too much from the experience of small islands, even when the islands in question are “as important as continents” (Mauro, 1961: 4). But it would also be unwise to read too little. Madeira’s sugar revolution was one of several decisive points of fracture in the early transition from feudalism to capitalism. Taken in isolation, any of the factors identified in these two essays can be explained away as essentially non-capitalist. The shift in property relations mandated a “weak” rather than the “strong” compulsion towards rising productivity. The movement towards modern plantation slavery was modest at best. The pace of landscape transformation was rapid, but Madeira was a small island. The growth of sugar production on Madeira outstripped its medieval forerunners, but remained a far cry from the rivers of sugar that flowed from Brazil and the Caribbean in subsequent centuries.

Taken as a whole, however, these multiple ruptures with medieval patterns suggest that something new was taking shape. Perhaps most telling, the crisis of Madeira’s sugar complex did not provoke a collapse of world sugar production. Capital and expertise flowed from Madeira to new frontiers, above all in São Tomé and later Brazil. For Madeira was but one leg of a great frontier journey, sustained by the endless search for new opportunities to appropriate nature’s free gifts, gifts that included human nature no less than fertile soil and abundant forests. Nor was Madeira exceptional. The frontier movement towards São Tomé, accomplished by the 1550s, was bound up with a broader movement of global ecological fix. The turbulence of the mid-sixteenth century, punctuated by the 1557 financial crisis and dramatized by recurrent state bankruptcies throughout western Europe, were bound up with a systemwide revolution in the relations between humans and the rest of nature. Northern Europe’s timber frontier shifted from Poland to Norway (Malowist, 1960; Moore 2010b); the center of silver production moved from Central Europe to Peru (Moore 2010d); the copper frontier moved from Slovakia to Sweden (Moore 2007: chapter two). These were pivotal moments in the world ecological revolution of the long seventeenth century (Moore, 2010a, 2010b). If regional shifts were nothing new, before the sixteenth century never had these frontiers moved so rapidly, and across such vast spaces.

What accounts for this rupture with medieval patterns? In a word, commodification. Sugar of course had long been a commodity produced for long-distance trade. But after the 1450s, as we see in Madeira, production for the market was joined to the commodification of land and labor. This triple helix of commodification – sugar, land, and labor – explains the competitive dynamism of successive sugar revolutions across the early capitalist Atlantic, and with it, the rapid exhaustion of the local conditions necessary to sustain such dynamism. Regional commodity revolutions owe their “revolutionary” character to the scale and speed with which capitalist and territorialist agencies appropriate nature’s free gifts. On Madeira, the greatest of these free gifts were derived from the forest and the soil. At some point in the early sixteenth century, the opportunities for appropriating these original sources of wealth contracted. Rising fuel costs intersected with soil exhaustion to undermine the socio-ecological basis of labor productivity. Market demand for sugar remained favorable many decades to come. Indeed, they were more favorable than during the boom years of the late fifteenth century. The Crown even cut taxes in the midst of the crisis (1515), but to no avail (Magalhães, 2009: 159).

In the end, nothing could overcome the Portuguese Atlantic’s sylvan poverty. Given the slow regeneration of the forests, we would expect to see an industry dependent on rapid forest exploitation to expand quickly and collapse precipitously. We might then expect to see periodic, but short-lived, revivals of that sector, given favorable price movements and some measure of forest regeneration. And this is just

what we see. Madeira experienced short-lived sugar booms over the next century (Mauro, 1983). But it never again scaled the commanding heights of the world sugar economy, which is after all the point. Early capitalism's boomtown regions were vast and varied, precisely because this ecological regime depended on the endless conquest of the earth to sustain the endless accumulation of capital, the real basis of which was labor productivity.

Beginning in this first sixteenth century, regional crises were resolved through global expansion, the global ecological fix (Moore, 2010a, 2010b, 2011a). Given sugar's biophysical particularities and therefore the limited possibilities for expansion within Europe, the global ecological fix entailed overseas expansion. And not merely expansion as event. The long sixteenth century was defined by *expansion as permanent movement*. The political ecology of competition on the world market, emerging in turns spectacularly and tentatively, underpinned the secular tendency towards regional socio-ecological exhaustion. This moved Europe's civilizational expansion from an occasional episode, to a way of life. Between the 1530s and the 1670s, Europe's territorial and capitalist powers extended their geographical hegemony from three to seven million square kilometers (Chaunu, 1959: 148). The sugar commodity frontier was not responsible for all of this, but little of it was conceivable without sugar and its triple helix of commodification.

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