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Fuelwood in Colonial Brazil

The Economic and Social Consequences of Fuel Depletion for the Bahian Recôncavo, 1549–1820

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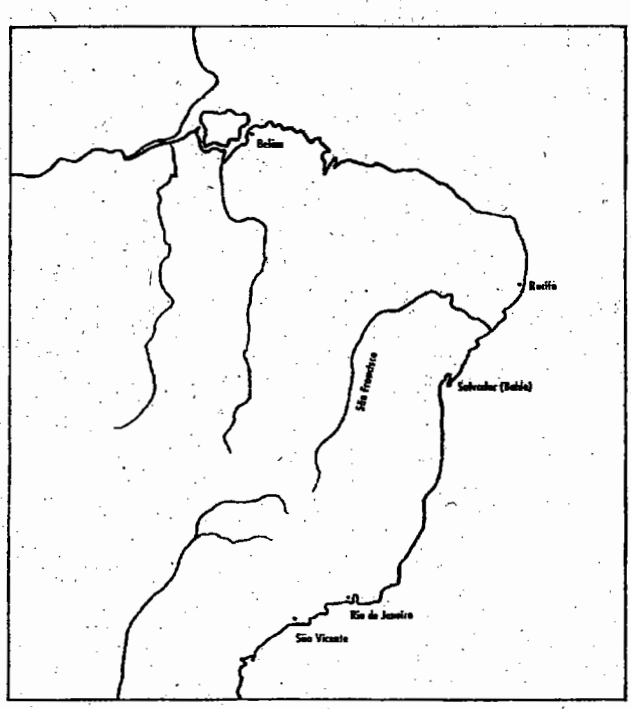
Among the various tasks that constituted the daily routine of Brazil's sugar economy, collecting fuel from the colony's plentiful forests was among the most extensive. In addition to preparing land for planting, cutting cane at harvest, and refining it at the mill, African slaves through four centuries had the additional burden of gathering the crucial energy source that fuelled the sugar mill. This article is in part a study of that resource's depletion and of sugar production's detrimental effect on Brazil's Atlantic forest. But it is more immediately an examination of the impact that the forest's retreat had on the fortunes of the colonial capital, Bahia, located in northeastern Brazil.[1] Fuel's increasing scarcity increased labor and capital costs related to fuel supply, exacerbated elite social conflict, multiplied petitions to the Crown, and eventually dictated the adoption of more efficient firing technology. Moreover, activities that vied with the sugar mill's furnaces for fuel contributed to the contest, in which all colonists participated, for one crucial natural resource: wood.

Discovery of the Forest

At the height of the Bahian sugar harvest, a view from the bluffs of the Bay of All Saints contained a great deal of smoke, for all along the northern shoreline, to a few kilometers inland, a considerable array of fires pushed arching columns into the prevailing southeasterly winds. The simple process of boiling the water and impurities from sugarcane's viscid juice, an essential stage in sugar refinement and one requiring large quantities of wood fuel, was in full swing. Ashes to ashes, the cooling clouds of smoke came finally to settle on what remained of Brazil's once primeval forests. With rarely a pause, the fires of the sugar mills burned as many as nine months of the year, more than twenty hours of the day and six days of the week, as long as there was fuel to feed them. And to the smoke-filled eyes of the early Portuguese, the fuel capacity of the Brazilian forest was boundless.

Portuguese, Italian, and Spanish explorers, the people who initiated the expansion of Europe, came from an environment that had long been stripped of its trees. In fact the entire Mediterranean seaboard, except a few isolated and coveted pockets, had been bereft of forests for centuries. Growing populations and the growing material demands for ships of discovery, war, and trade continued to make European wood resources increasingly scarce and costly, thus explaining the general amazement European sailors expressed at the sight of the New World's plentiful forests. When the Portuguese, during the earliest stage of their quest for the African route to the East, came across one particularly heavily forested island, the first they would colonize, they named it "Madeira," meaning "wood." Poet-adventurer Luís de Camões wrote a century and a half later that the island was



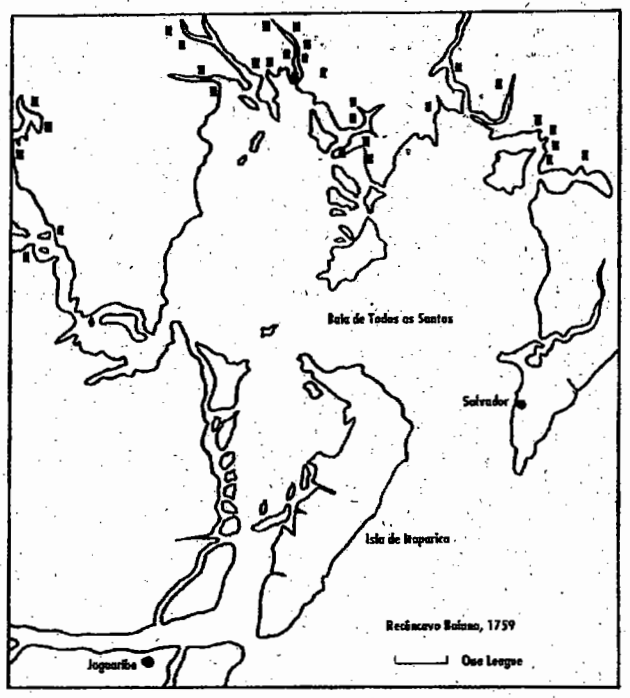


Figure 1 (left) *Colonial Brazil, drawn by author.* ***Figure 2 (right)*** *The Bay of All Saints, 1759. Salvador, the colonial capital, was the point of embarkation for sugar exported to Europe. Sugar mills clustered along the bay's northern arms and estuaries. The map in figure 2 was drawn by the author, after a 1759 map by José Antônio Caldas, whose original utilized a mushroom of rising smoke to represent each mill.*

more renowned for its namesake than for any other particular fame.[2] In 1500, en route to the spices of India, Pedro Alvares Cabral bumped into the South American continent and christened it "Land of the Holy Cross." The name that finally stuck originated in the red dyewood commonly called *pau-brasil* (brazilwood), South America's first trade contribution to the Portuguese colonial empire. To the doughty sailors of the fifteenth-century Mediterranean, wood was neither unremarkable nor unappreciated.[3]

The first important Brazilian export was wood, but the more important second commodity, cane sugar, could not have made its unrivaled contribution to colonial development had Cabral encountered a land of fewer trees. As if to claim parity of worth with precious metals, the nature of sugarcane dictated that it be processed by fire; and unless the purifying flames were applied soon after harvest, the touch of the refined product would be significantly lessened. To make this rapid procedure possible, large quantities of firewood had to be within easy reach of the sugar mill's furnaces. Before the mid-eighteenth century, wood and its by-product, charcoal, were the only practical sources of fuel. Any attempt at sugar production without a ready stockpile of forested land would not succeed no matter how favorable other environmental factors such as climate and soil.

Despite the delight of early arrivals to Brazil's tree-blanketed northeast, the novelty of the bounty quickly receded. Residents of wood-rich regions often perceive timber, lumber, and firewood to be as common as oxygen in the air. But, in the way that an oxygen shortage causes desperate burning in the lungs, rapid destruction of Bahia's virgin forests forced millers and planters, shipbuilders and carpenters, brick makers and tanners, even common folk living in the city, to grasp for their share of a steadily diminishing resource.

Fuel Requirements at the *Engenho*

The Bahian sugar mill, known as the *engenho*, was simply the combination of apparatus by which planters turned cane into varying qualities of crystallized sugar. The engenho pressed juice from the cane, boiled it, purged it, graded it, and then boxed it for transport to the city of Salvador where it awaited the near-annual convoy arrival for shipment to European markets. The mill also represented a concentration both of capital (in the form of machinery, buildings, and slaves) and political power in the hands of the *senhor de engenho*, a proto-capitalist who not only held extensive cane plantings, but also held the sugar region's essential mechanical means of production. In the Recôncavo, a fertile crescent of land surrounding the Bay of All Saints, life, work, religion, trade, planter aspirations, and natural resources centered on the engenho, a quasi-urban, quasi-industrial entity on the rural, colonial landscape. The sugar mill fueled Bahia's economic and demographic growth, and Brazil's forests fueled the mill.[4]

Estimates of the expense of fuelwood as a commodity in sugar production vary according to the sources and periods analyzed. One study indicates that in 1752 firewood amounted to 10 percent of finished sugar's selling price; as a percentage of cost, the figure would probably be greater.[5]

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Another source reveals that fuel costs in Bahian engenhos were often much higher (see table 1).

Although fuel expenses never dominated engenho account books, the cost of fuel generally stood at about one-fifth of total operating costs. Fuel costs were probably even greater than some numbers in the table suggest. The mill could either employ its own slaves, oxen, and salaried labor in gathering firewood or it could purchase fuelwood, sometimes more cheaply, from those who cut the forests independently. Engenho Sergipe in 1611 and Engenho São Caetano recorded little or no fuel expenses yet both must have used fuel, so fuel-associated costs were not always properly categorized. These two mills ostensibly paid little to outside fuel suppliers, but they would still have engaged their own capital in the collection of local firewood. The higher transportation and livestock costs of the mills at São Caetano and Buranhaem, whose reported fuel expenditures are about half the average, support this contention. For any given volume of cane refined the mill required at least half as much fuel. Hence, the average oxcart or boat servicing mill that did not purchase fuel from outside sources could be expected to haul large quantities of firewood and to do so over greater distances than it did either fresh-cut cane or finished, boxed sugar. For many mills, transportation, livestock, and equipment costs unavoidably included fuelwood-related expenses, especially in cases where the mill used its slaves and other capital to gather wood, making total cost of fuelwood acquisition greater than the table reflects.

Labor in the Forest

Getting fuel to the fire was a labor-intensive operation. Initially, mill owners found abundant forests at their front doorstep, but the double onslaught of land clearing for agriculture and timber felling for fuel and construction soon pushed this important resource far from the mills' easy reach. The competitive advantage switched from mills having local fuel sources to mills located at the water's edge where firewood from other locations could be easily delivered. In many instances fuel traveled long distances over water to the mill. The forests of Jaguaribe, located more than seventy kilometers south of mills on the bay's north shoreline, were a primary fuel source. The Jesuit André João Antonil suggested in 1711 that Jaguaribe's forests alone could supply sufficient fuel for all the mills of the Recôncavo at water's edge.[6] Just how crucial Jaguaribe's forests were to sugar production was made evident in 1671 when a general Indian rebellion expelled the colonists from many southern areas including Jaguaribe, Cachoeira, Camamu, and Maragogipe. Author and inventor Juan Lopes Sierra noted the impact of expulsion: "Everything dealing with provisions was missing throughout the south, and the northern part lacked the necessary items for the sugar mills such as wood, forms, bricks, tiles and crates. Because of this the mills had to close. With production halted, commerce ceased."[7] Even before the 1670s, many mills at the bay's shoreline depended on fuel sources far from their base of operation. José da Silva Lisboa, the colony's inspector of the royal forests in the late-eighteenth century, added as sources of fuelwood Itaparica and its neighboring isles located northeast of Jaguaribe in the southern part of the bay—"a voluminous article of commerce" that the islanders sold to sugar mills as well as to the citizens of Salvador.[8]

Fuelwood, from its felling to its fiery destruction, might require as many as four modes of transportation, consuming significant outlays of labor, time, and capital. The first and most dangerous movement was from vertical to horizontal: the actual felling of the tree. Male slaves, largely those newly arrived from Africa, throughout much of the year felled by ax centuries-old hardwoods, under the watchful eyes of foremen. In Jaguaribe the

Table 1 Distribution of Bahian engenhos' annual expenses, 1611–1822, as percentage of total expenses

Mill	Years	Fuel	Salaries	Slaves	Food	Medicine	Equip.	Trans.	Livestock	Misc.
Sergipe	1611–12	1.4	27.0	4.3	16.0	1.3	30.0	3.0	–	4.7
Sergipe	1634–35	26.0	33.0	4.1	6.0	–	24.0	3.0	–	3.1
Sergipe	1643–52	20.0	26.0	8.2	7.9	–	35.0	1.1	0.2	–
Sergipe	1669–70	18.0	14.0	13.5	3.8	–	17.2	–	–	–
Sergipe	1707–16	20.1	20.5	18.7	13.1	0.8	8.3	8.0	0.8	10.5
Lages	1711–1800	19.0	14.4	14.6	30.0	2.5	13.5	1.0	3.2	1.4
S. Caetano	1726–1800	–	13.4	12.3	30.5	0.6	14.7	10.0	15.4	3.1
Avg. Mill	1751	11.8	20.6	18.9	11.3	3.1	28.0	–	9.6	1.7
Buranhaem	1796	8.5	12.1	10.7	21.4	3.9	11.6	5.9	18.8	7.2

A dash signifies that account books for particular years do not utilize the category in question and may, or may not, include them under another category. The author carried over to the table any errors in the original documents.

Source: Stuart B. Schwartz, *Sugar Plantations in the Formation of Brazilian Society: Bahia, 1550–1835* (New York: Cambridge University Press, 1985), p. 222. Data that Schwartz consulted for Engenho Sergipe are from wider sources than data published as *Documentos para a história do açúcar* (Rio de Janeiro, Brazil: Instituto do Açúcar e do Alcool, 1956) and to which many researchers have had access. Schwartz's data include information drawn from the Arquivo Nacional da Torre do Tombo, Lisbon, Portugal, and the Archivum Romanum Societas Iesu, Rome, Italy. Statistics for Engenho São Caetano are from the Arquivo Distrital de Braga, Coleçao Sao Bento, Portugal. Statistics for Engenho Buranhaem are from caixa 46, pacote (1802), Arquivo Nacional do Rio de Janeiro, Rio de Janeiro, Brazil.

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work commenced in July, for August was the beginning of the annual cane harvest, which often stretched into May of the following year.[9] It is possible that fuelwood harvesters in the North practiced the same mass felling technique that future coffee planters in the South employed. A large number of trees on the side of a hill, all standing in close proximity and often tethered to one another by limbs and lianas, would each be cut to within inches of felling and then, finishing off the largest, all felled together with a domino effect. "It was the foreman's task to decide which was the master tree, the giant that would be cut all the way through, bringing down all the others with it. If he succeeded, the entire hillside collapsed with a tremendous explosion, raising a cloud of debris, swarms of parrots, toucans, songbirds, and, from the woodsmen, a shout of joy and relief."[10] If the foreman failed, the woodcutters entered a precarious and unsettled environment to topple what remained of the wavering widow-makers.

If the trees fell any distance from a waiting oxcart they were moved in their entirety by any of several methods, depending upon the terrain. On relatively level ground the limbed logs were rolled on poles or skidded behind oxen; however, in most other cases, whether it was uphill or down, slaves dragged the heavy timber with ropes and chains to points where oxen could be hitched to the logs. During the rainy season the slippery mud made for easier pulling, but once the trees were at roadside, bucked into manageable lengths, and loaded into oxcarts, the mired roads threatened the life expectancy both of the oxen and the carts. One of the colony's English residents, Henry Koster, maligned the oxcarts, which he asserted too frequently turned over due to their narrow wheel gauge; some planters worked their tongue-dragging oxen literally to death in the harsh task of hauling firewood.[11]

At land's end workers removed the firewood from oxcarts and carefully stacked small boats with the proper proportion of large, medium, and small pieces for efficient firing. From there the fuel sailed straight to the mill, provided the mill was at bayside. If not, there was at least one more transportation break.

Antonil described a number of independent persons who divided this immense labor among themselves.[12] Professional woodcutters worked their own slaves, but may not have owned oxen and carts for transporting their goods and instead hired independent teamsters for that purpose. Men called *arrais* often privately owned and managed the sailing vessels, but millers also employed sailors, slaves, and their own boats in order to buy fuel direct from the woodcutters and avoid paying freight charges, which escalated as the forests receded. Antonil recommended that the senhor de engenho have at least two vessels so one could return while the other set sail, testimony to the distances traveled. Mills that still had locally accessible firewood probably worked their own human capital, when available, to feed the furnaces.

Both cane and fuel were measured by the *tarefa*, a unit of volume equal to that necessary for a day's production at the mill. The tarefa of firewood equalled eight cartloads, and the tarefa of harvested cane was twenty-four cartloads.[13] While initially each mill probably consumed only one tarefa (eight carts) of fuel per day, by 1583 Fernão Cardim reported that Bahia's increasingly powerful mills required as many as twelve carts for a sixteen-hour day of milling; in 1710, Antonil explained that between twenty-five and thirty carts of cane were milled per day, requiring twelve to fifteen carts of fuel; the academic Vilhena, writing in 1802, calculated that a mill converted to an efficient furnace would consume between twelve and sixteen carts of fuel each twenty-four hours. Vilhena complained that ignorant and obstinate senhores de engenho nevertheless still used antiquated furnaces that consumed no less than one cartload per hour.[14]

In the harvest of 1650–51, the Jesuit-owned mill Sergipe de Conde milled sugar 224 days out of the total 310-day harvest (stoppages and the observance of religious holidays account for the 86-day difference).[15] Sixty years later Antonil reported that *engenhos reais* like Sergipe de Conde consumed in their six fiery furnaces 2,500 cartloads of firewood per harvest.[16] This means the mill consumed eleven carts per day.[17] Lay planters did not observe Catholic holidays as rigorously as did the Jesuits, meaning that their average number of milling days and total consumption may have been higher. Even if the mills observed by these contemporaries were somewhat larger than the average, a reasonable figure for the colonial period would be eight to ten carts of firewood per day per mill. Since employers expected every ax-wielding laborer to stock one full cartload of fuel per day, this would suggest that every operating mill employed between eight and ten laborers in cutting, dragging, and stacking firewood. It required forty oxcart trips from the forest edge to fill the hold of a large sailing bark, which had a capacity of five tarefas. Whatever the number of carts making those trips, two skilled teamsters manned each. As many as four sailors and a master manned the boats themselves, which "follow one right after the other, without halt."[18] The number of hands required for 36 Bahian mills in 1583, 63 mills in 1610, 146 mills in 1710, and 180 mills in 1758 illustrates Vilhena's simple statement that "[i]n the woods significant numbers are required to cut [and haul] firewood."[19] Based on these estimates, in 1758 Bahia's mills consumed more than 3,300 cubic meters of fuel per day (18.3 cubic meters per mill per day), involving close to 4,000 men in its harvest and transport during much of the year. This labor force drew from a total population of 72,833 in the sugar-producing Recôncavo. During one year's harvest, the Recôncavo's mills consumed approximately 750,000 cubic meters of fuel. None of these calculations include fuel consumption for firing clay, distilling rum, cooking meals, tanning leather and furs, or producing charcoal. Sugar production alone pushed the forest back at a breakneck pace.

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Labor at the Engenho

The life of the sugar mill stemmed from its consuming center. Fire was so integral to the workings of the engenho that Brazilians employed the epitaph *"fogo morto"* ("the fire is out") to identify inoperative mills, no matter the reason for their expiration. One colonial cartographer indicated Bahian mills on his map with the mushroom-like symbol of rising smoke. Antonil described the sugar mills' multiple furnaces as "truly devouring mouths of woodland, a prison of perpetual fire and smoke, a living image of the volcanoes Vesuvius and Etna, and almost of Purgatory and Hell themselves."[20]

Hell it was for the poor African souls allotted the task of keeping the fires stoked; tending fire frequently came as an assignment for medical and penal reasons. The sick, who might benefit from a good sweat, and the chained, intractable slave were both sent to the mouths of the furnaces in hope that the heat of the flames and the humid Bahian summer would remove from their constitutions whatever it was that adversely affected their productivity. One contemporary believed that stoking the fires along with hydrating clay constituted the worst jobs at a mill because these were the only individuals who could not secretly dip into the sweet product of their labors as a way to fend off hunger. A fire tender likely had much more with which to concern himself. Besides the skin burns that radiant heat and ballistic embers caused there was the possibility of falling into the furnace, although the construction of some mills minimized this danger. An insubordinate slave at the fire door was chained as much to keep him from running off as to deny him even the freedom of taking his life in the flames, an event that occurred on at least one occasion.

Building the fires was a job that required some architectural skills. The average six furnaces, one per kettle, were arrayed along the boiling house's outer, basement walls. Since the floor of the furnace could be a significant distance from the bottom of the kettle on the floor above, a structure of firewood spanned the gap (see figure 3). Using a long pole called a *trasfogueiro,* workers placed large logs crossways on top of each other, supporting gradually smaller pieces up to the top. In the early stage of boiling, the more fire the better, but the process became more delicate as the semi-purified juice moved to new receptacles, and the fire tender had to pay strict attention to his superiors. Too little heat and the juice would not boil; too much and the kettleman had to throw cool water in the vessel to keep the precious fluid from boiling over. If the foreman above and the slave below maintained proper temperatures, the resulting sugar was of higher quality and could be finished more quickly.[21]

Some smaller fires were apparently designated to burn softer hardwoods, including white mangrove and cashew among others, for although these woods had lower heat potential they rendered ashes that were essential in making lye *(decoada)* to further purify the cane juice. Important enough to be saved from one harvest to another, workers raked ash from the furnace floor and placed it in a heated brick recess from which it could be taken as necessary. Once the ashes had been shoveled into smaller, perforated tubs, boiling water was filtered through the ashes and then mixed with the juice boiling in the cauldrons.[22] The ashes of particular tree species were regarded as essential to the processing of sugar for they were key to its purity and whiteness, the qualities that fetched the highest prices. Senhores de engenho included this fact in arguments for preservation of the forest.[23]

Competition for a Dwindling Resource

As an essential, expensive, and increasingly scarce commodity, competing mill owners frequently argued over fuelwood. Although blood ties often connected these lords of agriculture, such links did not include the bonds of charity. The removal of one length of timber or the trespassing of one wayward, cane-trampling ox could throw cousins into sometimes bloody dispute.[24] Foremen who oversaw plantings and cuttings on the fringes of the mills' property had the added responsibility of defending both crops and fuel from sneaking neighbors. A 1690 altercation in which familial ties had no mollifying influence took place when two Jesuit priests of the Engenho Pitanga discovered a group of men from António da Rocha's mill in Jesuit woodlands. When the priests attempted to obstruct the depredations the mob verbally insulted them and beat them with the stolen goods.[25]

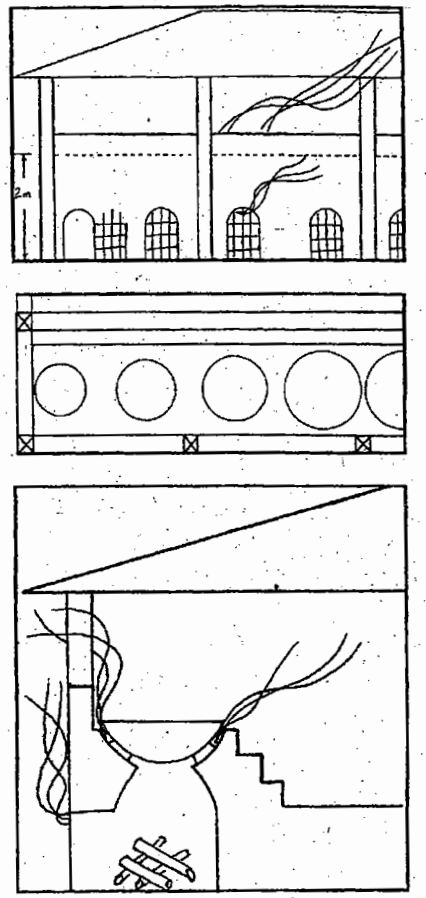

Figure 3 *Plan of a flueless eighteenth-century furnace house drawn in three elevations: front, side, and top. All drawings by the author.*

Top *Front view of the furnace house, showing the grated fire door of each furnace and the open terrace above. Note the great distance between furnace floor and kettles.*

Middle *Top view demonstrating the arrangement of the large copper kettles over each furnace. Larger mills utilized six kettles, the juice passing from the largest to the smallest during processing.*

Bottom *Cut-away side view of the furnace house, showing the internal dimensions of the furnace, the absence of a flue, and the working floor.*

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As pockets of forested land diminished in size and increased in distance from the mills, the scale of the fuelwood conflict escalated. By the mid-seventeenth century, however, mill owners turned to more formal means than theft to acquire what remained of an increasingly costly natural resource. In 1679 Pedro Garcia Pimental received special attention from the Crown concerning his exclusive right to exploit the woodlands that encircled his mill at Cahicabo. The prince-regent, soon to become Dom Pedro II, learned that certain heirs to those lands were planning to construct a mill not far from Pimental's, "which would be greatly prejudicial to both as it is not possible that the site has enough firewood for them, and from which act damage to the conservation of that state would ensue." Reminding his royal officials about related legislation his predecessors had passed, the regent forbade construction of any mill within a one-league circle of Pimental's mill and ordered that no tree could be removed from the woods of that prescribed area for any reason, unless those doing the clearing sold the wood as fuel to the Pimental mill at the current market price. This order insured that the surrounding forests would be used only for fueling the mill.[26]

In July 1680 the regent received a formal list of grievances from the municipal council at Salvador concerning the deleterious effects the large number of mills had on the sugar industry as a whole. The council confirmed that there was not enough firewood. Once cut, forests could not be replenished in less than twenty years, and trees required considerably more growing time than that if mills were to continue burning fuelwood in the sizes and quantities they were accustomed to using. Although the council and residents were aware of royal decrees setting minimum distances for new mills from neighboring mills, arguments over what that distance was and whether the space had to be wooded caused serious quarrels and lawsuits. The council's recommendations to the Crown fell firmly behind the senhores de engenho. Existing sugar mills, they said, should have precedence over upstart neighbors in the exploitation of firewood within one full league of their furnaces, for "it is more useful...to conserve one [engenho] for many years than to lose two in a brief time."[27]

On 3 November 1681 the regent, paraphrasing much of the council's letter as justification, prohibited construction of new mills within one-half league of existing mills.[28] That he cut in half the suggested one-league law is evidence that the king received conflicting pressure. Less than three years later the Salvador city council, for reasons unexplained, reversed its position. Their letter dated 5 August 1684 claimed that the woodlands of the Recôncavo were such that mills could often be established closer even than half a league without the slightest damage to production. The opposite was the case, they argued, for if one mill owner could hoard many acres of unused forests, less sugar would be produced and at greater cost.[29]

The desire of the planter class to escape their dependence on the senhores de engenho, whose monopoly over milling services promoted occasional high-handedness, was a primary stimulus to sugar mill proliferation. Despite the huge initial outlay in capital (slaves, waged employees, milling machinery, and transport vehicles) and the difficulties inherent in mill ownership, many planters had both the wealth or credit and the ambition to pursue milling operations on their own land. Hence the ongoing battle over how many mills could be built in a limited area was in part a contest between rival classes; senhores de engenho attempted to bar planters from acquiring any means of production beyond the land's inherent fertility. Declaring a dearth of firewood when new mills were to be built too close to their own was a means to that end.

The Impact of Fuel Scarcity

Production figures seem to support the mill owners' appeals. Brazil's three hundred working mills squeezed two million *arrobas* of finished sugar from the 1650 harvest. Nevertheless, in 1670, even with an increase of two hundred mills, the colony produced about the same volume.[30] While mill proliferation might have promoted a more equal distribution of income among the landed elite and ostensibly expanded productive capacity, actual production stagnated. Fuel scarcity was not necessarily a limiting factor in Brazilian sugar production at this point, but fuel shortages were significant enough that senhores de engenho somewhat successfully invoked this concern as a weapon in defending their interests. Planters during 1650–70 invested in processing capacity rather than in expanding cane plantings.

Statistics from the 1650–51 harvest at the Jesuit-run Engenho Sergipe de Conde, however, shed light on fuelwood scarcity's impact on sugar refining. Refining was interrupted on eighty-three days of the 310-day harvest period from August to May. Sixty of those interruptions were due to Sabbaths and religious holidays; the remaining twenty-three days of inactivity were divided among various causes: bad weather accounted for three days, five days were devoted to mechanical repairs, a lack of cane stopped the mill once. Fuel shortage was the reported cause for shutting down on fourteen separate days.[31] Insufficient firewood, in this particular mill and during this particular year, accounted for 61 percent of unwanted, reported production stoppages. There is no way to discern what caused the fuelwood shortages. Potential causes included bad weather, insufficient labor, lack of foresight on the part of the sugar master, and inadequate carts and boats for transportation. But as the distance of the forest from the mill increased, as a growing population demanded more wood for construction material, cooking, and shipbuilding, the complications in keeping sufficient amounts of fuelwood at the mill increased. Fuel supply became far less reliable than cane supply.

The firewood shortage at the mill had less to do with overall forest reserves than with inability to move sufficient amounts of fuel to areas of sugarcane production. As late as 1807 the author Rodrigo de Brito commented that talk of wood being in short supply was fiction. Cutting wood was just part of plantation expansion. Yet he conceded the bigger reality: the price of wood

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would continue to increase as the distance between mill and forest grew more quickly than the forests could be replenished.[32]

Despite senhores de engenho's statements suggesting the contrary, the debate among planters, millers, and other interested parties over fuel reserves was not about the availability of fuel but its accessibility. Bahia's forests stretched for miles into the interior; there was theoretically enough wood for everyone many times over. The problem was getting access to that far-flung wealth. Trees any distance inland were as good as nonexistent. Unlike some areas, such as the United States where relatively light conifers could float down even unnavigable rivers, Bahia's predominantly non-floating hardwood trees had to be shipped from the river bank, thus limiting woodsmen to the distances they could navigate. Even if there had been more conifers in the forests of northeast Brazil to float downriver, these would not have served as well for fuel.

Nature produced a wealth of forest resources, and generally the only cost to those who needed those resources was labor. The double benefit from minimizing labor and using the cheapest modes of transportation suggests that forests receded from the edges of navigable water more quickly than they receded from the mills themselves. Hence, most mills at water's edge, even before they exhausted the woods on their own lands, bought wood more cheaply from those who cut and hauled it from the banks of the bay and rivers. Attempts to limit the construction of new mills to a distance of one league may have had the additional intent of barring aspiring planters' access to water. Mills in the interior, however, while relying heavily on expensive oxen and manpower to move their cane, wood, and finished sugar, also had advantages. Interior, untouched lands were reportedly more productive, and distances to fuel sources were invariably shorter.[33]

Even when true scarcity threatened the viability of the sugar trade from time to time, senhores de engenho were loath to invent, adapt, or adopt new milling methods. It took centuries before a critical shortage of fuelwood forced millers to take note. Bahian millers then benefited from the experience of their competitors in the West Indies, who suffered from a far earlier and more severe depletion of fuel resources and therefore devised more efficient and alternative means of fueling their mills.

Part of human existence and survival involves predation on the surrounding environment by the economic system hunter, gatherer, or capitalist. And despite the importance of certain cultural and religious factors in conditioning the intensity and extent of human impact, the major determinant is population density. Even before the expansion of its culture, Europe's economic philosophy—whether in farming, mining, irrigation, or logging—had been to exploit natural resources to the ends that technology permitted. Native American cultures also exploited nature; the difference resided first in numbers, but also in the exploiter's intentions. Where Brazil's indigenous peoples were unanimously satisfied with daily subsistence, Europeans imported the idea that economic growth was a worthy end in its own right. Colonists could not, with satisfaction, simply produce for themselves what was meet for the day at hand. Bahia's sugar mills, like those of the West Indies or other Brazilian provinces such as Pernambuco and Rio de Janeiro, would single-handedly attempt to satisfy the world. But the growth of sugar production could not be sustained without technological progress. As has happened many times since in Bahia, technology ran up against scarcity, and either new technology had to be developed to leap scarcity's recurring obstacles or sugar interests would have to face the agony of economic stagnation. Nature's limitations had the final word: her many gifts were finite. Colonial Brazil's sugar producers faced only one option, to use what remained more efficiently.

In the bounteous land of colonial Bahia efficiency was a concept almost unheard of when it came to using natural resources. Planters and millers alike were interested in improved technology, but improvement meant expanding sugar production, and this was accomplished by adding more slaves, more acreage, and by squeezing more cane juice with more powerful mills. Although firewood amounted to a considerable portion of mills' total costs, little was done to use it prudently until the early-nineteenth century.

The Roots of Fuel Scarcity

The most extensive firewood destruction occurred even before the first cane cuttings were planted, when planters cleared the land. José da Silva Lisboa explained that the *massapé*, the black, unctuous soil that turned to a quagmire in rain, also produced the best cane yields, attracted the highest land prices, and had the best quality of trees. This exceptionally fertile soil was both the origin and result of the trees it anchored. The accumulation and decomposition over many centuries of leaves, downed timber, and other organic material on top of a layer of clay formed a coveted soil type for the perennial sugarcane. Silva Lisboa claimed that in some places this ground had been planted profitably for over sixty years without lying fallow or adding fertilizer; but he also observed that once the fertility diminished, a planter had to wait years for the land to recover.[34] Most planters simply moved to virgin, fertile forest instead.

Land clearing and fuelwood gathering were not complementary jobs. As Lisboa noted, "The planting of cane commences with the cutting and felling of the trees, if the plantation is made on new ground. When the forest is virgin, composed of woods that are enormously thick and large, if there is the possibility for them to be sawn, they are made into planks for sugar crates; otherwise all is reduced to ash....The smaller, remaining firewood is piled into mounds called *covairas* and fire is set to them until all the wood is consumed."[35] Forested land was burned over so that it would produce to planter expectations, although the practice wasted expensive firewood. Nevertheless, because of this burning the mills' fuelwood resources disappeared as cane plantings expanded into new areas.

The condition and form in which firewood was prepared for the furnace also contributed to the inefficient use

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of wood resources. Contemporaries observed that it was common to burn green or unseasoned wood. It is generally recommended that timber cut for firewood should be stripped completely of its bark and left to dry in the open air at least two to three months. At the peak of the harvest, when milling often halted for occasional interruptions of firewood supply, the mill did not wait even an extra day beyond the delivery date for fuel to dry. The caloric potential of green timber, containing from 60 to 90 percent moisture, might be compared to that of a wet, tightly rolled newspaper. A fresh-cut log with the minimum 60 percent moisture content provides less than 80 percent of the useful heat created by an air-dried log of 20 to 30 percent moisture content.[36] Every degree of heat that the furnace applied to boil moisture from the steaming, hissing wood represented energy that could not be applied to the cane juice it was intended to boil. Mills that stockpiled quantities of firewood during the off-season may have had fairly dry wood to fuel the furnaces during the early part of the harvest, but such stockpiles would have been exceptional.

In addition to burning green wood, mills burned wood in large pieces. Vilhena estimated that many logs put on the fire wholly intact were as large as .66 meters in diameter; this corroborates Sampaio e Melo's claim that some fire logs were so enormous that a man could not put his arms around them.[37] A piece of wood burns more efficiently as the ratio of oxygen-exposed surface area to volume increases. The circumference of a large round log exposes the smallest surface area possible, thereby impeding the critical processes of drying and pyrolysis.[38] Split firewood would obtain better heating and fuel-use efficiencies. However, mill operators likely considered splitting an operation too labor intensive due to the daily volumes involved.

The inefficient construction of the furnaces themselves added considerably to resource waste. Until the late-eighteenth century, mill operators largely ignored the fuel-saving claims of furnace inventors. In 1656, Juan Lopes Sierra claimed his new furnace would save one-third the fuel that other furnaces consumed and offered his patented plans for a price of 100 *milréis*. He reminded millers of the costs involved in gathering firewood, including the great distances traveled and the number of slaves required.[39] Most mill owners, either out of ignorance or a lack of faith in the claims of such entrepreneurs, did not invest in either the plans or the new construction (see figure 3, p. 185).

Throughout the colonial period, chimneys and flues that would direct the application of heat were almost unknown. Smoke, heat, and flame escaped through any opening in the furnace. As late as 1802, Vilhena described operating mills in which the fires were 2.2 meters below the kettle bottoms. Newer mills, at the time of his writing, had reportedly cut that distance in half, also cutting wood consumption. Fourteen years later, Koster described the sugar refining process as sloppy: "Ovens [are poorly made,]...enormous quantities of fuel are consumed, and the Negroes who attend to ovens are soon worn out." He thought the operations slovenly, with owners paying little attention to the "minutiae of business."[40]

During the first half of the nineteenth century millers showed greater interest in furnace innovations, suggesting that the costs of fuel finally had a recognizable impact on prodigal practices at mills. The Bahian Recôncavo had few rivals with such profitable conditions for growing sugar, and for this reason Brazil was late to adopt specific improvements. The extremely fertile *massapé* soils; proximity to the source of African slaves; long harvest season; vast forest reserves; a large, sheltered bay; and an extensive system of navigable rivers on which to transport goods and people cheaply gave Bahian sugar planters sharp advantages over their West Indian counterparts. Yet these advantages may have been deterrents to progress. Sampaio e Melo, in 1812, explained:

> The quantity of firewood that abounds in this country has been cause for the inhabitants not to study the merits of economizing it; but now that the forests are lengthening themselves from the *engenhos*...it is necessary to study this branch of physics which in the northern countries has made great improvements even in the kitchen's fires....If abundance has been the cause of our tardiness, necessity begins to cause our industry. Firewood has increased greatly in price in the past twenty years in this region; and if we do not imitate the industry of the inhabitants of Barbados and Martinique, our sugar will not be able to compete in price with theirs in Europe.[41]

Through much of the colonial period, nature's abundance was the strongest argument against attempts at conservation.

Figure 4 *Large team of oxen hauling a cartload of logs, not necessarily for fuel. Note the smoke rising on the horizon. Drawing by Percy Lau reproduced with permission from the Instituto Brasileiro de Geografia e Estatistica, Rio de Janeiro, Brazil.*

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Buying into the Engenho da Ponta in 1806, Manoel Ferreira da Camara, well-educated, liberal, and a colleague of Brazil's leading politician José Bonifácio de Andrada e Silva, revamped his furnaces in such a way that he saved two-thirds of the average fuel consumed.[42] Although there is no record of the actual changes made to the boiling apparatus, Ferreira may have adopted the Jamaica train system that had been earlier developed and accepted in the West Indies.

The Jamaica train, or any of its many variously named versions, had several advantages over older furnaces. As opposed to the old Spanish train configuration in which each kettle had its own fire, the Jamaica train had only one fire and its heat was directed by means of a flue over an array of kettles. Although the process was slower than the old process, significant savings in firewood convinced senhores de engenho to adopt it. More importantly, the Jamaica train burned bagasse—the dried cane husk wrung of its juice—as well as wood, or a mixture of both. Prior to this, mills either threw bagasse into the water, clogging shipping lanes, or spread it over empty fields to be dried and burned as a fertilizer. Although its use created new problems for the mill and even influenced the varieties of cane grown (some were more volatile than others), millers had an alternative fuel to the increasingly costly wood.[43]

Other Fuel Consumers

If sugar mills had been the only firewood consumers in the Recôncavo the intensity of local conflicts and deforestation might have been less notable. But there were other demands on the forest that competed directly with people whose interests were tied to sugar. Salvador's city dwellers faced the same fuel scarcity and price increases as their rural neighbors. In 1672 city residents could not gather even a small bundle of firewood near the city because private parties owned all the nearby wooded land. The city council suggested that wooded properties near the city should be bought, even if a specific tax had to be levied, to remedy this inconvenience.[44] Estimated late–nineteenth-century per capita annual fuel consumption was approximately two cubic meters, and it is likely that this consumption rate had changed little since the late-colonial period.[45]

The mills' ancillary operations themselves were often the most serious competitors for declining fuel resources. Most mills took advantage of sugar processing by-products to make rum for consumption both locally and abroad. In 1759, José Antônio Caldas counted seventy-one distilleries in the Recôncavo providing three different grades of spirits.[46] Some, especially clerics, wrote of the moral consequences that this drink had on the population; others warned against being too liberal with alcohol for slaves. However, relative to the furnace house, these operations and their demands for firewood were small.[47]

Another fuel contender at the mill was the kiln for ceramic production. The Bay of All Saints had an ample natural supply of clay, and besides the well-known ceramic sugar forms whose conical shape gave the name "Sugar Loaf" to more than one mountain, the engenho needed a great deal of brick and tile. These items were used in the walls and extensive roofs of the furnace and purging houses, the chapel, and the master's *casa grande*. Mill owners constructed the furnaces themselves using brick and mortar for the lower walls, but the bricks in the furnace's upper reaches were set in clay because intense heat made mortar friable.

Gabriel Soares de Souza, writing in 1587, gave the impression that all mills had their own wood-burning brick kiln, but there was some debate about the cost effectiveness of these kilns. Some people concluded that the kiln required too much large firewood, which included that of the mangrove in whose roots bedded oysters, slaves' favorite food. Antonil suggested that the pottery works required the labor of six slaves and were so expensive that buying from other sources would be advisable. Antonil concluded that "if the senhor de engenho has many people, much firewood and mangroves in excess for oystering, he can also have a pottery house, and this workshop will serve to increase the greatness, utility and convenience of the mill."[48]

Other sectors of Bahia's economy also relied upon the forests for fuel. Even before the arrival of the first royal governor in 1549 there was a lime kiln at Bahia. In 1550 Afonso Jorge received $800 *réis* for his employment there, and Estevão Fernandes was paid the sum of 5$160 réis for supplying it with firewood.[49] Again in 1587, Soares de Souza wrote of three lime producers on the island of Itaparica where quarried chunks of limestone were placed in vaulted kilns and pulverized by the heat from large wood fires burning "day and night." When oyster shells could be easily accumulated, these were the preferred source of lime because they required less fuel per pound of product.[50] As the colony grew, demand for lime increased.

Although there are scant references to charcoal and its use in Bahia, there is evidence of a sizable trade from as early as 1549. Charcoal, used in smelting and blacksmithing, was made by burying closely stacked wood underground or in earth-covered piles and setting to it a slow, controlled burn. In this process of distillation wood lost half its volume and half its total heat potential but gained the advantage of burning both hotter and cleaner. Between April 1550 and August 1552 five named individuals delivered a total of 2,051 bags of charcoal to the city of Salvador's smithies.[51] According to an established contract, the city paid each *carvoeiro* (one who produces charcoal) thirty-five réis per bag. Of the five named, some were also listed as lumber dealers and canoe makers, suggesting that the requirements of gathering and processing wood for charcoal allowed sufficient time for other related economic activities.[52]

In the early-eighteenth century leather goods became a major factor in Bahia's yearly exports, requiring large amounts of the forest's organic fuel. Salvador's hinterland, especially that bordering the cattle trough of the San Francisco River, produced numerous herds used for traction (turning mills, hauling carts), meat, tallow, and shoe and crude leather. In 1757 Bahia exported over ninety-five thousand pieces of leather and 14,585 bales of tobacco tightly sewn into sizable

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hides. So important were trees to the leather industry that in 1760 cutting mangroves for fuel was prohibited by law in many provinces because such activity caused harm to hide processors who relied on the tree's bark for tannic acid. Anyone who cut those trees that had not been peeled of their bark faced a large fine and three months of imprisonment. Cattle hides, which like cut sugarcane decayed if left untreated, were turned into durable leather by boiling them in a tank of water with the mangrove bark. In 1746, Pernambuco had twenty-seven separate tanning operations employing more than three hundred slaves, many of them undoubtedly peeling bark and cutting firewood. Although there are no similar records for Bahia, the numbers could be even greater since Salvador annually exported more leather than any other port.[53]

In the early-seventeenth century, Bahia established the colony's first whaling industry, and although overfishing of the bay and local coasts quickly removed the captaincy from its preeminent position, the processing of whale oil remained a significant employment until about 1825. Even in 1802, Vilhena recorded at least two large whale oil refiners in Bahia, one at the Ponta da Armação das Baleias on the northern tip of the island of Itaparica, and another on the beach at Itapoan on the Atlantic coast. The German scientist Karl Friedrich Philipp von Martius gave the impression there were smaller operations in the vicinity as well.[54] The fuel necessary for reducing wale blubber, at least in the case of the Itaparica armação, relied on the same sources as did sugar mills.[55]

Shipbuilding, although never requiring large amounts of firewood, elicited complaints from colonists who saw Salvador's royally administered shipyard as a detrimental competitor for highly valued hardwood species *sucupira* (*Bowdichia virgilioides* H.B.K). By 1587 Soares de Souza counted more than fourteen hundred watercraft on the bay, one hundred of them more than ten meters long, a number that still insufficiently served the needs of commerce.[56] Most of these boats and the best oxcarts, milling machinery, and bushings were made of *sucupira* and had to be frequently repaired and replaced. Hence shipbuilding competed for firewood indirectly by competing for the materials required to build small boats and carts that transported fuel to the mills. Planters and millers also often hauled timber to the shipyard, which lacked its own means of transporting primary materials. In 1704 Salvador's municipal council informed the king that the practice of building large ships in Bahia (six galleons in the past seventeen years) had caused millers, sugar planters, and tobacco planters "general ruin." As they had done previously, they petitioned the king to move the royal shipyards south to Ilheus, Camamu, or Rio das Contas where wood was still abundant and there was less danger of damaging the local sugar economy.[57]

Bahia also exported a significant amount of lumber and a variety of wood products. Although most of these were species specific, wood in the holds of Portuguese ships bound for Europe, the West Indies, or other parts of Brazil could not be used to fuel the fires of sugar mills. Little is known about the extent and value of the Brazilian lumber trade outside of brazilwood, but the inventories of goods shipped out on fleets bound for Lisbon provide some indication. Of the twenty-nine items that José António Caldas listed as cargo on the fleet of 19 November 1757, twelve were wood products, ten were packaged in wood (crates and barrels of varying sizes), and four were processed by the application of heat from wood fires. Whatever the total commercial value of the lumber trade, the volume was substantial. Trees left Brazil in significant numbers as sawn lumber, protective packaging, and spent heat (see table 2).[58]

Even Portugal used wood from Bahia's forests to fuel her fires, at least by the late-eighteenth century. The same fleet in 1757 carried 146,200 billets of firewood to Lisbon, and in 1796 Bahia exported at least 14,875 pieces to Lisbon at the price of two réis each. Much of the latter shipment seems to have been destined for the royal kitchens and probably served as ballast on the voyage.[59]

Table 2 Exports of timber, containers, and fuelwood-dependent goods from Bahia to Portugal, 19 November 1757 merchant convoy

Timber products	
Unmilled flitches (dozens)	680
Planking (dozens)	130
Beams	235
Ship timbers	1,000
Carriage switches	37
Vine trellis poles	1,897
Billets of firewood	146,200
Planks of *vinhatico*	180
Planks of *piguia*	28
Roof timbers	615
Logs of cabinet wood	
Jacarandá	356
Sebastiao de Arruda	3,068
Wooden containers (varying sizes)	
Barrels	1,271
Crates	12,756
Fuelwood-dependent products	
Units of sugar	12,751
Bales of tobacco	143
Units of leather	89,177
Furs	5,058

Note: Quantities not otherwise designated are counted in units of "each."

Conclusion

In the Bahian Recôncavo, as in all of Brazil's sugar producing regions, the extraction of firewood was an operation extensive in scale and of widespread concern. Even in a tropical climate where domestic heating had almost no impact, fuelwood was among the colony's most crucial economic products. Through most of the colonial period, fuel acquisition for Brazil's fuel-dependent enterprises was generally never more than a nuisance. But by the end of the eighteenth century senhores de engenho, tanners, whalers, and distillers alike began to experience the crisis West Indian colonies had suffered a century before. Although Brazil's sugar industry commenced a full century before its West Indian competitors, the sheer extent of Brazil's Atlantic forests averted the exigency for two and a half centuries. Firewood's increasing scarcity

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impinged upon the scale and direction of sugar mill proliferation, multiplied the costs and complexities of production for all fuel-dependent entrepreneurs, and even dictated the articulation of the terms in which social conflict played out.

The impressive scale of fuel demand also affected the colonial division of labor. The planting, caring for, and harvesting of sugar cane on the colony's coastal lowlands abetted the importation of millions of slaves to Brazil, the majority of all Africans who arrived in the Americas.[60] But not all slaves received a machete or hoe. The ax played as large a role as any tool in the ongoing attempt to make the colonial venture a success.

In his 1944 study of the state of the sugar industry in Bahia, Adrião Caminha Filho marveled at the colonial mansions that had been financed by the old sugar mills and concluded that "without doubt, the status of the past mills was far more prosperous than that of the present, modern sugar factories." In addition to exhausted soils and cane blight the "lack of fuel is one of the most serious difficulties of the local industry," and many mills were forced to stop constantly as a result. Echoing his predecessors' oft-repeated concerns, Caminha Filho declared that "there are no longer any forest reserves in the Recôncavo, and the situation is so grave and offers such serious prognostications for the industry that it requires a very careful study."[61] Brazil's eminent sociologist and geographer, Gilberto Freyre, writing about the same time, reminded those concerned that "the warning call of the first governor of Pernambuco against the devastation of the forests remained a voice crying in an ever increasing desert."[62]

The Recôncavo's wood resources continued to decline through the nineteenth century as they had done the previous three centuries. The succeeding generation of planters inherited the legacy of their parents and made little or no effort to preserve or renew accessible sources of fuel. Despite the crucial relationship between the colony's prosperity and nature's well being, smoke-filled skies continued to obscure the vision of a less promising future.

Notes

1. The official name of the city is Salvador (Saviour), but in their correspondence kings and viceroys referred to the city as Bahia (Bay), also a common practice today. I refer to Bahia in this article, except where there is ambiguity as to whether I mean the city or the province Bahia. Bahia remained the capital until 1763, when Rio de Janeiro became the capital.
2. Luís de Camões, *Os Lusíadas* (Porto, Portugal: Porto Editora, 1992), chap. 5, v. 5. However, sugar production had nearly completed Madeira's deforestation by the time of Camões's passage.
3. For the causes and state of deforestation in Portugal, see José Bonifácio Andrada e Silva, *Memoria sobre a necessidade e utilidade do plantio de novos bosques em Portugal. . .* (Lisboa, Portugal: Academia Real de Sciencias, 1815). The author is unaware of contemporary related research for Portugal or Iberia. For southern Europe in general see J. V. Thirgood, *Man and the Mediterranean Forest: A History of Resource Depletion* (New York: Academic Press, 1981).
4. Students of the colonial sugar economy have often mentioned the vast quantities of fuelwood that sugar production required, but rarely have they elaborated. See Stuart B. Schwartz, *Sugar Plantations in the Formation of Brazilian Society: Bahia, 1550-1835* (New York: Cambridge University Press, 1985), for the most comprehensive economic study in English to date. Schwartz's research substantiates fuel's importance but does not address its social and environmental implications. Vera Lucia Amaral Ferlini, *Terra, trabalho e poder: o mundo dos engenhos no Nordeste colonial* (São Paulo, Brazil: Editora Brasiliense, 1988), touches on the fuel issue but emphasizes what occurs above the flames. José Wanderley Araújo Pinho, *História de um engenho do Recôncavo, 1522-1944* (São Paulo, Brazil: Companhia Editora Nacional, 1946), is an early source with an excellent description of furnace innovations, but suffers from understatement of fuel's total cost.
5. Wanderley Pinho, *História de um engenho* (1946; reprint, São Paulo, Brazil: Companhia Editora Nacional, 1982), p. 245, n. 8. Pinho arrives at a figure of 10 percent by dividing the selling price of seven loaves of sugar (2$800) by the cost of the one tarefa of firewood (2$500) consumed in its refining. Colonial Brazil's basic money of account was the *réal* (plural *réis*). One thousand réis was called a *milréis*. The dollar sign's location three places from the decimal point was simply a means of punctuation, much as American English uses the comma in numbers beginning in the thousands. Thus, ten réis would have been written $010; one thousand réis would have been written 1$000. Brazilian coinage often referred to in primary sources (e.g., tostão, vintem, cruzado) was made up of réis, but the actual value changed from one century to another.
6. André João Antonil [pseudonym of Giovanni António Andreoni, S.J.], *Cultura e opulência do Brasil, por suas drogas e minas*, . . (São Paulo, Brazil: Companhia Melhoramentos, 1976), bk. 2, chap. 8.
7. Juan Lopes Sierra, *A Governor and his Image in Baroque Brazil: The Funeral Eulogy of Afonso Furtado de Castro do Rio de Mendonça*, trans. Ruth Jones (Minneapolis: University of Minnesota Press, 1979), p. 43.
8. José da Silva Lisboa, "Carta muito interessante para o Dr. Domingos Vandelli," (1781), *Annaes da Biblioteca Nacional do Rio de Janeiro* 32 (1910): 496.
9. Antonil, *Cultura e opulência*, bk. 2, chap. 7. Indian labor may have also been used for fuel cutting (as it was in timber extraction for lumber), but the author found no mention of it in Bahian sources.
10. Warren Dean, "Coffee Dispossesses the Forest," *With Broadax and Firebrand: The Destruction of the Brazilian Atlantic Coastal Forest* (Berkeley: University of California Press, forthcoming), chap. 8.
11. Henry Koster, *Travels in Brazil*, ed. C. H. Gardiner (Carbondale: Southern Illinois University Press, 1966), p. 169; and Luiz dos Santos Vilhena, *Recopilação de notícias Soteropolitanas e Brasílicas Contidas em XX cartas*, 3 vols. (Bahia, Brazil: Imprensa Official do Estado, 1921), 1:184.
12. Antonil, *Cultura e opulência*, bk. 2, chap. 8.
13. The oxcart had a capacity of 2.04 m^3 (1.7 x 1.5 x 0.8 meters); hence, the *tarefa* of fuel equaled approximately 16.3 m^3. See Antonil, *Cultura e opulência*, bk. 2, chap. 8; and Koster, *Travels in Brazil*, p. 169, for dimensions. A tarefa of fuel in 1711 cost 2$500 réis, or about sixteen times the value of a woodcutter's daily wage ($160 réis).
14. Fernão Cardim, *Tratados da terra e gente do Brasil* (Rio de Janeiro, Brazil: J. Leite & Cia., 1925), p. 320; Antonil, *Cultura e opulência*, bk. 2, chap. 6 and 8; Vilhena, *Recopilação de notícias*, 1:184.
15. Stuart B. Schwartz, "Colonial Brazil, c. 1580-c. 1750: Plantations and Peripheries," *The Cambridge History of Latin America*, ed. Leslie Bethell, 7 vols. (Cambridge, England: Cambridge University Press, 1987), 2:434-35.
16. Antonil is probably describing Sergipe de Conde, with which he was most familiar. See Antonil, preface to *Cultura e opulência*, p. 213. An *engenho real* was a mill run by waterpower rather than animal traction.
17. The daily usage rate is calculated by dividing 2,500 carts of firewood by 224 days of milling.
18. Antonil, *Cultura e opulência*, bk. 2, chap. 5.
19. Vilbena, *Recopilação de notícias*, 1:185. For the number of mills at Bahia see Cardim, *Tratados da terra e gente;* Antonil, *Cultura e opulência;* Vilhena, *Recopilação de notícias;* and Schwartz, "Colonial Brazil," 2:431.
20. José António Caldas, *Notícia geral de toda esta capitânia da Bahia*, Edição Facsimilar (Salvador, Brazil: n.p.). Antonil, *Cultura e opulência*, bk. 2, chap. 8.

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21. For descriptions of fire handling at the mill see Antonil, *Cultura e opulência*, bk. 2, chap. 8; and Vilhena, *Recopilação de notícias*, 1:184, 186-87.
22. See Antonil, *Cultura e opulência*, bk. 2, chap. 8; and Koster, *Travels in Brazil*, p. 166.
23. João Rodrigues de Brito, *Cartas econômico-políticas sobre a agricultura e commércio da Bahia* (Bahia, Brazil: Imprensa Official do Estado, 1924), p. 97. Brito quotes Manoel Ferreira da Camara's statement that when the proper woods could not be secured for making lye the fabrication of sugar suffered immeasurably.
24. Antonil, *Cultura e opulência*, bk. 1, chap. 3.
25. Royal Order to António Luís Gonçalves da Câmara Coutinho, Lisbon, 7 December 1690, vol. 1, Royal order #92, Ordens Régias, Arquivo Público do Estado da Bahia, Salvador, Brazil.
26. *Documentos Históricos*, 110 vols. (Rio de Janeiro, Brazil: Biblioteca Nacional do Rio de Janeiro, 1928-55), 27:260-61. The Portuguese colonies, like those of Spain, were ruled and administered in every branch of colonial life by the crown and its multitudinous appointed officials. Affairs from the momentous to the trivial merited their attention. During this period Pedro ruled as regent, after deposing by signed agreement his brother Affonso VI, becoming Pedro II after Affonso's death in 1683. The best evidence suggests that the one-league law commenced in 1609 (see Brito, *Cartas econômico-políticas*, p. 96). It met with little success.
27. *Cartas do Senado: Documentos históricos do Arquivo Municipal do Salvador Bahia*, 5 vols. (Salvador, Brazil: Prefeitura do Municipio, 1951-62), 2:88-89.
28. Pinho, *História de um engenho*, p. 220.
29. *Cartas do Senado*, 2:128-29.
30. Stuart B. Schwartz, "Free Labor in a Slave Economy: The Lavradores de Cana of Colonial Bahia," *The Colonial Roots of Modern Brazil*, ed. Daniel Alden (Berkeley: University of California Press, 1973), p. 189. An arroba equals 14.7 kilograms.
31. Schwartz, "Colonial Brazil," 2:434-35. Although not critical to my argument, there is a small discrepancy between the data provided in the text of "Colonial Brazil" and that suggested by the graphic representation on the facing page. I have relied on the latter.
32. Brito, *Cartas econômico-políticas*, pp. 31-32.
33. Both Antonil, *Cultura e opulência*, pp. 101-102, and Vilhena, *Recopilação de notícias*, 1:174, discuss the pros and cons of waterside mills and those inland. The waterside mills' soils were exhausted, forests were depleted, and subsistence agriculture was inadequate.
34. Silva Lisboa, "Carta muito interessante," p. 499. Schwartz, *Sugar Plantations*, p. 107, discusses soil and climate.
35. Silva Lisboa, "Carta muito interessante," p. 499.
36. See *Fuelwood and Charcoal Preparation: An Illustrated Training Manual on Simple Tools and Techniques for Small-scale Enterprises* (Geneva, Switzerland: International Labor Office, 1985), p. 47, for the suggested time to allow wood to dry before burning. Percentage of moisture content is determined by comparing the timber's oven dry weight (0 percent moisture) with its initial green weight. The equation is [1 — (oven dry weight ÷ initial green weight)]. For this equation and average percent moisture in fresh cut timber, see *Fuelwood and Charcoal Preparation*, p. 46.
37. Vilhena, *Recopilação de notícias*, 1:196; Manuel Jacinto de Sampaio e Melo, *Idade de Ouro do Brasil*, no. 76 (22 September 1812), cited in Pinho, *História de um engenho*, p. 241; and Antonil, *Cultura e opulência*, p. 116, all describe the excessive size of firewood.
38. See David A. Tillman, *Wood Combustion: Principles, Processes, and Economics* (New York: Academic Press, 1981), pp. 17-33. Tillman also discusses wood's moisture content.
39. *Atas da Camara: Documentos Históricos do Arquivo Municipal do Salvador Bahia, 1625-1700* (Bahia, Brazil: Prefeitura Municipal do Salvador, 1944), 3:311.
40. Koster, *Travels in Brazil*, p. 165.
41. Sampaio e Melo, *Idade de Ouro*, in Pinho, *História de um engenho*, pp. 236-37.
42. Brito, *Cartas econômico-políticas*, pp. 81, 96.
43. For a comprehensive account of the numerous furnace innovations at Bahian mills in the nineteenth century see Pinho, *História de um engenho*, pp. 227-41.
44. *Atas da Camara*, 5:81. The king granted lands *(sesmarias)* to the citizens of Salvador on which pasturing and wood gathering were permitted, but they were inconveniently located in relation to the city.
45. An incident in Rio de Janeiro in 1800 provides some evidence. The Brazilian viceroy charged the English 25$800 réis for the fuel needs of four hundred fifty French prisoners that the English captured on the high seas. This charge was for 3,775 billets and 256 bundles of firewood for thirty-two days. Based on this example, the prisoners' consumption was approximately 120 wood pieces per capita per year, keeping in mind the greater efficiency likely exhibited due to the institutional nature of keeping prisoners. See Viceroy Conde de Reyerde to Captain Bulteel of the English Navy, código 68, vol. 16, f. 280, pp. 307-308, Arquivo Nacional do Rio de Janeiro, Rio de Janeiro, Brazil.
46. Caldas, *Notícia geral*, p. 445. Antonil, *Cultura e opulência*, appendix, stated the trade value of Recôncavo rum as 30,000 *cruzados* in 1710, a significant portion of Bahia's total exports. A *cruzado* was a gold coin worth 480 réis at the time.
47. The Jesuit Antonil, among others, makes frequent mention to the consequences of permitting slaves to drink. See Antonil, *Cultura e opulência*.
48. Gabriel Soares de Souza, *Tratado descriptivo do Brasil* (Rio de Janeiro, Brazil: Typographia Universal de Laemmert, 1851) in *Revista do Instituto Histórico e Geográfico do Brazil* (Rio de Janeiro, Brazil: Imprensa Nacional, 1853), 14:356; Antonil, *Cultura e opulência*, bk. 3, chap. 4.
49. Edson Carneiro, *A cidade do Salvador* (Rio de Janeiro, Brazil: Organização Simões, 1954), p. 108.
50. Soares de Souza, *Tratado descriptivo do Brasil*, 14:296, 355-56.
51. There is no record of the size of these bags of charcoal.
52. *Documentos Históricos*, vols. 37 and 38.
53. See Francisco Augusto Pereira da Costa, *Anais Pernambucanos*, 2d ed. (Recife, Brazil: Governo de Pernambuco, 1983-87), pp. 203-205; Caldas, *Notícia geral*, following p. 442.
54. Vilhena, *Recopilação de notícias*, 1:238. Johann Baptist von Spix and Karl Friedrich Philipp von Martius, *Viagem Pelo Brazil* (Rio de Janeiro, Brazil: Imprensa Nacional, 1938), pp. 273-76.
55. *Documentos Históricos*, 27:209. See also Myriam Ellis *Aspectos da pesca da baleia no Brasil colonial* (São Paulo, Brazil: n.p., 1958), pp. 55-70.
56. Soares de Souza, *Tratado descriptivo do Brasil*, 14:151. Diego de Campos Moreno claimed in 1612 there were more boats in Bahia than in the rest of Brazil combined; see Diego de Campos Moreno, *Livro que da razão do estado do Brasil*, published in *Hispanic American Historical Review* 29 (August 1947): 533.
57. For a sample of the municipal council's correspondence concerning the royal shipyard and its effects on the sugar economy, see *Cartas do Senado*, 3:4-5, 38-39, 42-43; and 5:98-101.
58. Caldas, *Notícia geral*, pp. 442-43. Millers reported sugar crates, made of softwoods that would not alter sugar's taste or color, as increasingly expensive. Ambrósio Fernandes Brandão, *Diálogos dos grandezas do Brasil*, ed. José A. Gonçalves de Mello, 2d ed. (Recife, Brazil: n.p., 1966), p. 159, was acquainted with individuals who with slave labor built and sold up to two thousand chests per year (*Diálogos*, p. 159). Sacks did not replace crates until the mid-nineteenth century.
59. *Balança Geral do Comércio de Portugal, 1796*, 11, 4, 8, folha 43, Biblioteca Nacional do Rio de Janeiro, Rio de Janeiro, Brazil; and Caldas, *Notícia geral*, following p. 442.
60. Philip Curtin, *The Atlantic Slave Trade: A Census* (Madison: University of Wisconsin Press, 1969), table 34, p. 119.
61. Adrião Caminha Filho, *A cana de açucar na Bahia* (Bahia, Brazil: Tipografia Naval, 1944), pp. 5, 36.
62. Gilberto Freyre, *Nordeste: Aspectos da influência da cana sobre a vida e paisagem do Nordeste do Brasil*, 3rd ed. (Rio de Janeiro, Brazil: José Olympio, 1961), p. 54.

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