The First Green Revolution: Debt Peonage and the Making of the Nitrogen Fertilizer Trade, 1840–1930

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To many historians, scientists, and agricultural experts, the term "Green Revolution" refers to the controversial array of programs and policies that introduced high-yield seeds, intensive irrigation techniques, herbicides, pesticides, mechanization, and petrochemical fertilizers to parts of the developing world during the 1960s and 1970s. Among the most profound consequences of this recent agricultural transformation was a vast increase in the amount of nitrogen available to farmers in Asia and Latin America. Through the application of imported synthetic fertilizers, these cultivators achieved increased yields of staple crops such as corn, rice, and wheat.

Numerous scholars have portrayed this twentieth-century intervention in world food production as the first human alteration of the global nitrogen cycle during the modern era.[1] Such a depiction is misleading. It obscures an earlier Green Revolution, beginning in the nineteenth century, during which companies and labor contractors transported millions of metric tons of nitrogen fertilizer and more than 100,000 workers across the globe, producing significant shifts in environments and labor conditions throughout the world. A comprehensive understanding of this First Green Revolution fuses two emerging research areas—global environmental history and transnational labor history. An investigation of the relationship between new forms of servitude that emerged in the Age of Abolition and the concurrent development of a worldwide fertilizer trade reveals that the changing nature of work is inextricably intertwined with the work of changing nature.

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[1] Treatments of the twentieth-century Green Revolution as the first extensive anthropogenic alteration of the nitrogen cycle include Dietrich Werner and William Edward Newton, eds., *Nitrogen Fixation in Agriculture, Forestry, Ecology and the Environment* (Dordrecht, 2005); Lance H. Gunderson and C. S. Holling, eds., *Panarchy: Understanding Transformations in Human and Natural Systems* (Washington, D.C., 2002), 37; David Tilman, "The Greening of the Green Revolution," *Nature* 396, no. 6708 (1998): 211–212; and Gordon Conway, *The Doubly Green Revolution: Food for All in the Twenty-First Century* (Ithaca, N.Y., 1997).

Between the 1840s and the 1930s, Peru and Chile exported hundreds of millions of tons of nitrogen-rich guano (dried bird excrement) and sodium nitrate ($NaNO_3$) to places as far-flung as California, Virginia, Prussia, Great Britain, and France. For farmers in North America and Europe, guano and sodium nitrate dramatically increased agricultural productivity during the final phase of the Industrial Revolution, which lasted from roughly the mid-1800s through World War I.[2] The widespread availability of imported fertilizers also facilitated a departure from organic "closed systems" of farming, in which nitrogen is cycled among soil, plants, animals, and people at the local scale, toward "open," energy-intensive approaches to agriculture that included additions of nitrogen from distant places.[3]

This major human intervention in the nitrogen cycle was closely linked to fundamental shifts in global labor relations during the Age of Abolition (1780s–1880s). In 1807, Britain outlawed the importation of African slaves to its colonial empire. The following year, the United States banned the importation of slaves, while in 1811, Spain abolished chattel slavery at home and in all of its colonies except the "sugar islands" of Cuba, Puerto Rico, and Santo Domingo. Despite such overwhelming victories for abolitionism, new forms of servitude emerged to replace those that faced extinction. Often these arrangements involved debt peonage, the repayment of loans with fixed periods of physical labor.[4]

Prior to the full-scale mechanization of mineral extraction, companies in Peru and Chile met the demanding labor requirements of guano and sodium nitrate mining by exploiting workers who were neither chattel slaves nor wage laborers. The Peruvian government banned slavery in 1854, but offset potential labor shortages with *la trata amarilla*, the so-called "yellow trade" in coerced Chinese workers. Between 1847 and 1874, at least 100,000 "coolies" from China came to Peru aboard an estimated 276 vessels. While many of these laborers toiled on cotton and sugar plantations, worked as domestic servants, or built railroads, thousands performed the arduous task of digging seabird feces. Although employers promised to free coolies from the bonds of servitude after three to five years of work, such releases rarely occurred.[5]

[2] As Eric Hobsbawm has convincingly argued, the full effects of the Industrial Revolution "did not make themselves felt in an obvious and unmistakable way—at any rate outside England—until quite late in our period; certainly not before 1830, probably not before 1840 or thereabouts"; Hobsbawm, *The Age of Revolution: Europe, 1789–1848* (London, 1962), 27. Others have used the term "second industrial revolution" to describe the period of the late nineteenth and early twentieth centuries in which such quintessentially "modern" technological devices as the telephone, the radio, the automobile, and the aircraft emerged. See, for example, Perry Anderson, "Modernity and Revolution," *New Left Review* 144 (March–April 1984): 96–113, here 104.

[3] During the nineteenth and early twentieth centuries, sodium nitrate was variously known as *salitre*, saltpeter, saltpetre, nitre, nitrate(s), and nitrate of soda. Peruvian guano contains approximately 15 percent nitrogen, while sodium nitrate contains approximately 16 percent nitrogen. T. M. Addiscott, *Nitrate, Agriculture and the Environment* (Cambridge, Mass., 2005), 51.

[4] I have used Seymour Drescher's timeframe for the Age of Abolition (1780s–1880s). Drescher, "Whose Abolition? Popular Pressure and the Ending of the British Slave Trade," *Past & Present* 143, no. 1 (1994): 136–166.

[5] Watt Stewart claims that 90,000 Chinese arrived in Peru during this period; Stewart, *Chinese Bondage in Peru: A History of the Chinese Coolie in Peru, 1849–1874* (Durham, N.C., 1951), 74. Arnold J. Meagher puts the number at 109,146; Meagher, *The Coolie Trade: The Traffic in Chinese Laborers to Latin America, 1847–1874* (Philadelphia, 2008), 222 n. 142. For ship numbers, see Walton Look Lai, "Chinese Indentured Labor: Migrations to the British West Indies in the Nineteenth Century," *Amerasia* 15, no. 2 (1989): 117–138, here 120. The term "coolie" may have originated as a derivation of the Tamil

Chilean nitrate firms used a similarly coercive labor regime known as the *enganche* system. In the 1880s, recruiters for the Nitrate Producers Association began enlisting migrant workers in Chile, Bolivia, and Peru. *Enganchadores*, literally "ones who press or trick others into performing a service," hosted raucous, liquor-soaked carnivals where they enticed migrant laborers with tales of the boomtown fortunes to be made in the Norte Grande, the northernmost region of Chile. Once these men signed on, they found themselves at the mercy of company agents who routinely ignored contractual obligations. Debt for his passage to the mines became the interminable bond that kept each worker toiling endlessly for his contractor.[6] As a result, the First Green Revolution—from the 1840s to the 1930s—not only represented an unprecedented human intervention in the global nitrogen cycle, it also relied upon a new configuration of transnational labor relations. Debt peons from China, Chile, Bolivia, Peru, and other regions of the Pacific world mined for the companies that exported nitrogen-rich compounds from South America's islands and deserts.

The fertilizer trade was instrumental in mobilizing new sources of nutrients and motivating innovative labor regimes. In an era in which modern technologies of movement, such as the train, the steamboat, and the steel-hulled clipper ship, began to compress the experience of space and time, capital rapidly exploited new zones of untapped resources.[7] Guano and sodium nitrate were valuable not merely because of their nitrogen content; they were prized because they could be transferred swiftly and inexpensively from South America's Pacific shores to the increasingly degraded soils of the Atlantic world.[8]

In a similar display of rapid transnational displacement, employers moved workers from their homelands to distant job sites. These relocations facilitated unprecedented labor control for those who organized the trade in debt peons. Mining companies and plantation owners, faced with a post-slavery world order, used new

word for wages, *kūli*. See Henry Yule and A. C. Burnell, *Hobson-Jobson: A Glossary of Colloquial Anglo-Indian Words and Phrases, and of Kindred Terms, Etymological, Historical, Geographical and Discursive*, new ed., ed. William Crooke (London, 1903), 250. In South America, the Caribbean, and the North American West, "coolie" was a derogatory term for cheap, servile laborers. In 1821, there were at least 41,228 slaves of African descent in Peru. Mario E. Del Rio, *La inmigración y su desarrollo en el Perú* (Lima, 1929), 38. On Peruvian abolition, see Carlos Aguirre, *Agentes de su propia libertad: Los esclavos de Lima y la desintegración de la esclavitud, 1821–1854* (Lima, 1993).

[6] Sergio González Miranda, *Hombres y mujeres de la Pampa: Tarapacá en el ciclo de expansión del salitre*, 2nd ed. (Santiago, 2002), 141–151; Michael Monteón, "The *Enganche* in the Chilean Nitrate Sector, 1880–1930," *Latin American Perspectives* 6, no. 3 (1979): 66–79; and Roberto Hernández-Cornejo, *El salitre: Resúmen histórico desde su descubrimiento y explotación* (Valparaíso, 1930), 138–166. Even highly innovative histories of the nineteenth-century global fertilizer trade overlook the unifying theme of Pacific world debt peonage. See, for example, Rory Miller and Robert Greenhill, "The Fertilizer Commodity Chains: Guano and Nitrate, 1840–1930," in Steven Topik, Carlos Marichal, and Zephyr Frank, eds., *From Silver to Cocaine: Latin American Commodity Chains and the Building of the World Economy, 1500–2000* (Durham, N.C., 2006), 228–270.

[7] Geographer David Harvey refers to "time-space compression" in *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change* (Oxford, 1989), 284–307. On the relation between new modes of transportation and the guano trade, see Kenneth Pomeranz and Steven Topik, *The World That Trade Created: Society, Culture, and the World Economy, 1400 to the Present* (New York, 1999), 127.

[8] Soil degradation implies "the temporary or permanent lowering of the soil's productive capacity." Decreasing soil fertility is one aspect of soil degradation. Others include erosion, salinization, acidification, pollution, and compaction. J. K. Syers, "Managing Soils for Long-Term Productivity," *Philosophical Transactions: Biological Sciences* 352, no. 1356 (1997): 1011–1021, here 1012.

configurations of the long-distance labor trade to extract maximum surplus value from their workers, relegating millions of men and women to what Moon-Ho Jung calls "the legal and cultural borderland between slavery and freedom."[9] Through contractual agreements and their attendant promises of steady work and entrepreneurial potential, the coolie trade and the *enganche* system isolated laborers from familiar landscapes and made quitting impossible for debt peons. Gunther Peck's notion of "the geography of labor mobility" offers a conceptual framework for understanding how the labor power of these workers became commodified through spatial dislocation. As Peck demonstrates in *Reinventing Free Labor*, labor contractors in the late-nineteenth- and early-twentieth-century North American West created structures of coercion and established relations of debt peonage by controlling the traffic in workers across vast spaces and between jobs.[10]

Like the labor conditions of the remote and inhospitable worksites that Peck profiles, guano extraction and nitrate mining were grueling jobs located in South America's most austere environments. Corporations that demanded regimented production schedules without seasonal relief had difficulty convincing small farmers to abandon their subsistence lifestyles and submit to new modes of capitalist work discipline. During the final phase of the Industrial Revolution, European and North American cash-crop production, from sugar beets to hops and cotton to tobacco, depended on an unprecedented acceleration of productivity from both a growing migrant labor force and thoroughly overworked soils.

Beginning in the mid-nineteenth century, input-intensive agriculture developed rapidly as farmers on both sides of the Atlantic attempted to achieve higher crop yields. In many cases, such "open" systems of farming replaced local recycling of nutrients and the widespread use of long fallow periods of soil recovery characteristic of traditional agriculture. Such shifts constituted a prolonged phase of "restlessness" for both the earth and those who reshaped its contours; additionally, this global explosion of productivity depended on new substitutions for outdated labor regimes and obsolete land-use practices.[11]

As a result, employers turned to debt peonage to solve the quandary of labor conscription in a geopolitical context where the African slave trade was increasingly outlawed. The hostile environments and the dangerous, backbreaking tasks of guano and sodium nitrate extraction magnified the unforgiving working conditions that itinerant miners faced, while the absence of institutional oversight in these remote mineral frontiers allowed the companies that profited from the lucrative fertilizer trade to use particularly coercive tactics. The global abolition of chattel slavery cre-

[9] Moon-Ho Jung, "Outlawing 'Coolies': Race, Nation, and Empire in the Age of Emancipation," *American Quarterly* 57, no. 3 (2005): 677–701, here 698.

[10] Gunther Peck, *Reinventing Free Labor: Padrones and Immigrant Workers in the North American West, 1880–1930* (Cambridge, 2000), 2.

[11] E. P. Thompson, "Time, Work-Discipline, and Industrial Capitalism," *Past & Present* 38, no. 1 (1967): 56–97. On Britain's agricultural transition away from frequent fallowing toward more intensive forms of cultivation that involved legume rotation and field grass husbandry, see Robert Allen, "Agriculture during the Industrial Revolution," in Roderick Floud and Donald McCloskey, eds., *The Economic History of Britain since 1700*, 2nd ed. (New York, 1994), vol. 1: *1700–1860*, 96–122, here 114; and Phyllis Deane, *The First Industrial Revolution*, 2nd ed. (New York, 1979), 39. For accounts of a similar transition in the American South, see Julius Rubin, "The Limits of Agricultural Progress in the Nineteenth-Century South," *Agricultural History* 49, no. 2 (1975): 362–373, here 363.

ated new labor shortages on proto-industrial plantations and in mines, and an array of brutally innovative indenture arrangements emerged to meet capital's pressing demand for cheap labor.[12] By relocating workers to isolated landscapes, labor bosses undermined a traditional repertoire of political, economic, and social alternatives for these laborers. Thus, in the late nineteenth and early twentieth centuries, the coerced migration of workers through debt peonage relations and the displacement of nutrients from the Pacific world toward the United States and Europe produced a double movement that revolutionized global agricultural production.

Despite its potential yields, the analytical terrain at the crossroads of environmental history and labor history has drawn the attention of few scholars. During the 1990s, Richard White urged his colleagues to reject "a larger tendency to define humans as being outside of nature," an approach that arises from a "disdain and distrust of those who most obviously work in nature."[13] White called for greater attention to the ways that humans have experienced "knowing nature through labor."[14] In 2008, Chad Montrie pushed White's argument further, encouraging scholars to think more concretely about how alienation from the products of our work produces estrangement from our environments. That same year, Thomas Andrews argued for heightened attentiveness to the processes that structure what he called "workscapes," places that are "shaped by the interplay of human labor and natural processes."[15] While a few historians have responded to these urgings, our growing awareness of the (quite literally) constructed nature of historical landscapes still needs extensive reworking.[16]

[12] For more on the development of industrial processes on Caribbean sugar plantations and in silver mines in the Americas, which predated Europe's Industrial Revolution, see Sidney W. Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (New York, 1985); and Peter Bakewell, *Miners of the Red Mountain: Indian Labor in Potosí, 1545–1650* (Albuquerque, 1984). On the use of Chinese debt peons as a solution to Peruvian labor shortages in the 1840s, see Michael J. Gonzales, "Chinese Plantation Workers and Social Conflict in Peru," in James Gerber and Lei Guang, eds., *Agriculture and Rural Connections in the Pacific, 1500–1900* (Burlington, Vt., 2006), 105–144, here 110. In the context of late-nineteenth-century Cuban sugar production, Rebecca Scott has made a similar argument for the relationship between the use of Chinese labor and the abolition of the African slave trade; Scott, *Slave Emancipation in Cuba: The Transition to Free Labor, 1860–1899* (Pittsburgh, 2000), 29.

[13] Richard White, "'Are You an Environmentalist or Do You Work for a Living?' Work and Nature," in William Cronon, ed., *Uncommon Ground: Rethinking the Human Place in Nature* (New York, 1996), 171–185, here 172. For similar claims, see John C. Berg, ed., *Teamsters and Turtles? U.S. Progressive Political Movements in the 21st Century* (Lanham, Md., 2002).

[14] Richard White, *The Organic Machine: The Remaking of the Columbia River* (New York, 1995), 3–29.

[15] Chad Montrie, *Making a Living: Work and Environment in the United States* (Chapel Hill, N.C., 2008), 7; and Thomas G. Andrews, *Killing for Coal: America's Deadliest Labor War* (Cambridge, Mass., 2008), 125.

[16] Lissa K. Wadewitz, *The Nature of Borders: Salmon, Boundaries, and Bandits on the Salish Sea* (Seattle, 2012); Thomas Miller Klubock, "The Nature of the Frontier: Forests and Peasant Uprisings in Southern Chile," *Social History* 36, no. 2 (2011): 121–142; Lawrence M. Lipin, *Workers and the Wild: Conservation, Consumerism, and Labor in Oregon, 1910–30* (Urbana, Ill., 2007); Gunther Peck, "The Nature of Labor: Fault Lines and Common Ground in Environmental and Labor History," *Environmental History* 11, no. 2 (2006): 212–238; John Soluri, *Banana Cultures: Agriculture, Consumption, and Environmental Change in Honduras and the United States* (Austin, Tex., 2005); Kathryn Morse, *The Nature of Gold: An Environmental History of the Klondike Gold Rush* (Seattle, 2003); and Karl Jacoby, *Crimes against Nature: Squatters, Poachers, Thieves, and the Hidden History of American Conservation* (Berkeley, Calif., 2001). For an earlier example of productive connections between labor history and environmental history, see Mart A. Stewart, *"What Nature Suffers to Groe": Life, Labor, and Landscape on the Georgia Coast, 1680–1920* (Athens, Ga., 1996). Geographers have long recognized the interconnectedness of social and ecological struggles. See, for example, Don Mitchell, *The Lie of the Land: Migrant Workers*

Such shifts in perspective require innovations in the conceptual structure of historical inquiry. The contours of ecosystems are notoriously evasive and rarely match the treaty-bound perimeters of nation-states; consequently, the study of human-ecological interactions through time necessitates a transnational viewpoint, even a transoceanic one. Writing history beyond national boundaries, in turn, generates new understandings of shifting labor practices and corresponding social transformations. Although Thomas Bender has become one of the most visible proponents of transnational history, younger scholars are supplementing his work with their own sophisticated critiques of nation-centered and comparative national histories. The hallmark of a transnational approach to the past, notes Micol Seigel, is that "Without losing sight of the 'potent forces' nations have become, it understands them as 'fragile, constructed, imagined.' Transnational history treats the nation as one among a range of social phenomena to be studied, rather than the frame of the study itself."[17]

Unfortunately, debt peonage research has tended to reify the framework of the nation-state. Although scholars of slavery and abolition have described and analyzed types of bonded labor, such as sharecropping, that emerged as a "shadow of slavery" in the postbellum U.S. South, few juxtapose these manifestations of indenture in the southern United States with equally coercive labor arrangements beyond the Atlantic world after slavery's demise.[18] Similarly, while Latin American historians have explored relations of debt peonage in national contexts, they have yet to reflect upon the ways in which the combined arrangements of the Pacific coolie trade and the *enganche* system offered an alternative transnational labor regime to the increasingly fragmented nineteenth-century Atlantic slave trade.[19] In 2000, David Brion Davis

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and the California Landscape (Minneapolis, 1996); and David Harvey, *Justice, Nature and the Geography of Difference* (Cambridge, Mass., 1996).

[17] Thomas Bender, ed., *Rethinking American History in a Global Age* (Berkeley, Calif., 2002); and Micol Seigel, "Beyond Compare: Comparative Method after the Transnational Turn," *Radical History Review* 91 (Winter 2005): 62–90, here 63. On the persistence of the historical profession's nation-centered focus, see José C. Moya, "A Continent of Immigrants: Postcolonial Shifts in the Western Hemisphere," *Hispanic American Historical Review* 86, no. 1 (2006): 1–28. Also valuable in this vein are the chapters in Antoinette Burton, ed., *After the Imperial Turn: Thinking with and through the Nation* (Durham, N.C., 2003). For an overview of the possible pitfalls and unacknowledged hierarchies characteristic of transnational history, see David Kazanjian and María Josefina Saldaña-Portillo, "Introduction: The Traffic in History," *Social Text* 92, vol. 25, no. 3 (2007): 1–7.

[18] Pete Daniel, *The Shadow of Slavery: Peonage in the South, 1901–1969* (Urbana, Ill., 1972). Important exceptions to this tendency include Sven Beckert, "Emancipation and Empire: Reconstructing the Worldwide Web of Cotton Production in the Age of the American Civil War," *American Historical Review* 109, no. 5 (December 2004): 1405–1438; and Matthew Pratt Guterl, "After Slavery: Asian Labor, the American South, and the Age of Emancipation," *Journal of World History* 14, no. 2 (2003): 209–241.

[19] Elizabeth Dore, "Debt Peonage in Granada, Nicaragua, 1870–1930: Labor in a Noncapitalist Transition," *Hispanic American Historical Review* 83, no. 3 (August 2003): 521–559; Mark Moberg, "Crown Colony as Banana Republic: The United Fruit Company in British Honduras, 1900–1920," *Journal of Latin American Studies* 28, no. 2 (1996): 357–381; Alan Knight, "Mexican Peonage: What Was It and Why Was It?," *Journal of Latin American Studies* 18, no. 1 (1986): 41–74; David McCreery, "Debt Servitude in Rural Guatemala, 1876–1936," *Hispanic American Historical Review* 63, no. 4 (1983): 753–759; and Friedrich Katz, "Labor Conditions on Haciendas in Porfirian Mexico: Some Trends and Tendencies," *Hispanic American Historical Review* 54, no. 1 (1974): 1–47, here 15–23. For comparative approaches, see Tom Brass, "Unfree Labour and Capitalist Restructuring in the Agrarian Sector: Peru and India," *Journal of Peasant Studies* 14, no. 1 (1986): 50–77; and Brass, "The Latin American *Enganche* System: Some Revisionist Reinterpretations Revisited," *Slavery and Abolition* 11, no. 1 (1990): 74–103. Calls for a "transnationalizing" of labor history include Michael P. Hanagan, "An Agenda for Transnational Labor History," *International Review of Social History* 49, no. 3 (2004): 455–474; Beverly J.

reminded the readers of the *American Historical Review*, "Eventually, the Atlantic Slave System did reach across the Pacific and was partially replaced by a Pacific labor system that included Hawaii and the Philippines and that drew on 'coolie' labor from India, China, and other parts of Asia."[20] Davis's remark can be expanded to link the work of debt peons in the Pacific world to the agricultural shifts that characterized the final phase of the Industrial Revolution in Europe and North America.

THE KEY ELEMENT OF THESE TRANSFORMATIONS was nitrogen, one of several macronutrients—including phosphorus and potassium—that plants need for survival. Nitrogen is a building block of nucleic acids, proteins, chlorophyll, and enzymes. The earth's atmosphere is composed of approximately 79 percent triple-bonded nitrogen gas (N_2), while the remaining 21 percent is oxygen, along with trace amounts of other gases. Despite the ubiquity of gaseous nitrogen, only a small percentage of this atmospheric supply is readily available to terrestrial organisms. Atmospheric N_2 is highly unreactive; most plants cannot use this nitrogen unless it is transformed into reactive (N_r) forms, including ammonium (NH_4) and nitrate (NO_3). One of the few pathways through which atmospheric nitrogen becomes usable to plants is biofixation, or the conversion of inert N_2 into organic compounds, such as amino acids, which are further transformed by microbes to produce NH_4 and NO_3. Biofixation can be carried out by *Rhizobium* bacteria attached to the roots of leguminous plants, including soybeans and clover, or by other free-living microbes, such as cyanobacteria. Lightning, volcanic activity, and forest fires, as well as high-temperature combustion of fossil fuels, can also produce the extreme temperatures necessary for the fixation of nitrogen. Additionally, the recycling of crop residues, manures, or human waste can help to preserve the pool of reactive nitrogen within an ecosystem.[21]

In the millennia following the Neolithic Revolution (ca. 10,000 B.C.E.), most agrarian societies began recycling human and animal waste. The Roman writer Lucius Columella (4–70 C.E.) urged farmers to "bring as food for newly ploughed fallow ground whatever stuff the privy vomits from its filthy sewers." Almost two millennia later, a Chinese imperial treatise from 1737 commented, "The southerners accumulate nightsoil in pits. They treasure nightsoil as if it were gold." Nutrient-rich manures even altered relations between pastoralists and sedentary peoples. For ex-

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Silver, *The Forces of Labor: Workers' Movements and Globalization since 1870* (Cambridge, 2003); and Marcel van der Linden, "Transnationalizing American Labor History," *Journal of American History* 86, no. 3 (1999): 1078–1092.

[20] David Brion Davis, "Looking at Slavery from Broader Perspectives," *American Historical Review* 105, no. 2 (April 2000): 452–466, here 454 n. 13.

[21] For more on human alterations of the nitrogen cycle, see James N. Galloway and Ellis B. Cowling, "Reactive Nitrogen and the World: 200 Years of Change," *Ambio* 31, no. 2 (2002): 64–71; D. S. Jenkinson, "The Impact of Humans on the Nitrogen Cycle, with Focus on Temperate Arable Agriculture," *Plant and Soil* 228, no. 1 (2001): 3–15; and Peter M. Vitousek et al., "Human Alteration of the Global Nitrogen Cycle: Sources and Consequences," *Ecological Applications* 7, no. 3 (1997): 737–750. An elegant treatment of the role of clover in world history can be found in Thorkild Kjærgaard, "A Plant That Changed the World: The Rise and Fall of Clover, 1000–2000," *Landscape Research* 28, no. 1 (2003): 41–49. On the role of phosphorus fertilizer in world food production, see Dana Cordell, Jan-Olof Drangert, and Stuart White, "The Story of Phosphorus: Global Food Security and Food for Thought," *Global Environmental Change* 19, no. 2 (2009): 292–305.

ample, in precolonial East Africa, manure from the cattle raised by Hinda clans fertilized the banana crops grown by neighboring Haya cultivators.[22]

Farmers around the world also discovered the value of cultivating nitrogen-fixing legumes, such as alfalfa, clover, peanuts, beans, peas, and lentils. As early as the fourth century B.C.E., Xenophon of Athens remarked that legume cultivation was a successful remedy for soil exhaustion. Likewise, the ancient Chinese ideogram "shu," which represented the soybean, had a row of vertical marks at its base to denote the relationship between the plant's root nodules and its soil-enhancing properties.[23] In the Americas, legumes featured prominently in the foodways of ancient civilizations. Archaeologists digging among prehistoric ruins in Peru unearthed so many peanut shells that they joked that the site "bore a strong resemblance to the main entry of Yankee Stadium after a Saturday game."[24]

During the nineteenth century, European and North American farmers began to abandon closed systems of nutrient recycling, which had connected neighboring urban and rural communities. Previously, poudrette (human excrement, dried and mixed with charcoal and gypsum), furnace ashes, ground bone, and dried blood from slaughterhouses had provided urban contributions to rural soil fertility. In return, city dwellers had consumed the produce of nearby farms. By the mid-1800s, open-ended systems arose, which depended on foreign commodities, including imported seeds, machinery, and fertilizers. These inputs often traveled great distances to reach the farms where they were applied.[25]

In 1857, Karl Marx summarized this transition: "agriculture no longer finds the natural conditions of its own production within itself, naturally arisen, spontaneous, and ready to hand, but these exist as an independent industry separate from it."[26] Guano and sodium nitrate were products of such an independent industry, and their

[22] Lucius Iunius Moderatus Columella, as quoted in Naomi F. Miller and Kathryn L. Gleason, "Fertilizer in the Identification and Analysis of Cultivated Soil," in Miller and Gleason, eds., *The Archaeology of Garden and Field* (Philadelphia, 1994), 38; *Qinding shoushi tongkao*, as quoted in Yong Xue, " 'Treasure Nightsoil as If It Were Gold': Economic and Ecological Links between Urban and Rural Areas in Late Imperial Jiangnan," *Late Imperial China* 26, no. 1 (2005): 41–71, here 60; and Roland Oliver, "The East African Interior," in J. D. Fage and Roland Oliver, eds., *The Cambridge History of Africa*, 8 vols. (New York, 1975–1986), 3: 621–669, here 640. For more examples, see Eugene Mather and John Fraser Hart, "The Geography of Manure," *Land Economics* 32, no. 1 (1956): 25–38.

[23] Kimberly B. Flint-Hamilton, "Legumes in Ancient Greece and Rome: Food, Medicine, or Poison?," *Hesperia* 68, no. 3 (1999): 371–385, here 373. In 1963, Hu Daojing analyzed Shang Dynasty (1600–1046 B.C.E.) bronze artifacts that featured the ancient character "shu." Hu argued that the marks on the lower half of this ideogram represented an early understanding of the soybean's role in soil fertility. See Hui-Lin Li, "The Domestication of Plants in China: Ecogeographical Considerations," in David N. Keightley, ed., *The Origins of Chinese Civilization* (Berkeley, Calif., 1983), 21–63, here 30. The nitrogen derived from increased legume cultivation helped to drive the dramatic expansion in Europe's agricultural productivity from 1750 to 1880. On this point, see G. P. H. Chorley, "The Agricultural Revolution in Northern Europe, 1750–1880: Nitrogen, Legumes, and Crop Productivity," *Economic History Review* 34, no. 1 (1981): 71–93, here 71.

[24] Gordon R. Willey, "Foreword," in Margaret A. Towle, *The Ethnobotany of Pre-Columbian Peru* (Chicago, 1961), ix.

[25] Richard A. Wines, *Fertilizer in America: From Waste Recycling to Resource Exploitation* (Philadelphia, 1985), 3. On the transition from so-called "closed systems" to open ones in European and U.S. history, see Susan Strasser, *Waste and Want: A Social History of Trash* (New York, 1999), 14–15; F. M. L. Thompson, "The Second Agricultural Revolution, 1815–1880," *Economic History Review* 21, no. 1 (1968): 62–77, here 64; and Arthur G. Peterson, "Agriculture in the United States, 1839 and 1939," *Journal of Farm Economics* 22, no. 1 (1940): 98–110.

[26] Karl Marx, *Grundrisse: Foundations of the Critique of Political Economy*, trans. Martin Nicolaus (London, 1973), 527.

widespread availability contributed to the emerging metabolic rift between the city and the countryside. The development of input-intensive agriculture was neither instantaneous nor inevitable. Regions of Europe and North America shifted away from tight nutrient-cycling loops between urban and rural communities at different times and with varying degrees of resistance.[27]

A handful of social reformers lamented this partition, begging their fellow citizens to bridge the expanding chasm between city and farm. In his 1862 novel *Les Misérables*, Victor Hugo wrote, "There is no guano comparable in fertility with the detritus of a capital. A great city is the most mighty of dung-makers. Certain success would attend the experiment of employing the city to manure the plain. If our gold is manure, our manure, on the other hand, is gold."[28] Twelve years later, a California writer compared the nutrient-cycling failures of his own city to those of Hugo's Paris: "Is it possible that San Francisco possesses no man of sufficient business far-sight to see that he might accumulate a mint of wealth by paying the city a round sum for the contents of its privy-vaults and sewers, and handling it on the suburban sand hills, and with it flooding the country with early vegetables?"[29] For the most part, however, such enterprising suggestions fell upon deaf ears.

A revolution in soil science, resulting in the development of manufactured fertilizers, hastened this evolving metabolic rift between the city and the country.[30] Prior to the mid-1800s, farmers, blacksmiths, and estate owners, lacking formal scientific training, developed what Steven Stoll has aptly labeled "dunghill doctrines."[31] These advances in European and North American agriculture contributed to prevailing understandings of soil dynamics and coalesced as commitments to the continued fertility of the land. In 1840, however, when German chemist Justus von Liebig published his groundbreaking treatise on fertilizer and soils, *Organic Chemistry in Its*

[27] Karl Marx frequently used the German term *Stoffwechsel*, or metabolism, when discussing productive relations between humans and nature. In his analysis of the rise of industrial agriculture, he built upon Justus von Liebig's pioneering soil science (see nn. 32 and 33) and introduced the notion of "an irreparable rift in the interdependent processes of social metabolism, a metabolism prescribed by the natural laws of life itself. The result of this is a squandering of the vitality of the soil, which is carried by trade far beyond the bounds of a single country." Marx, *Capital*, 3 vols. (1867–1894; repr., New York, 1981), 3: 949. For more on the centrality of the metabolic metaphor in Marx's writing, see Fernando Coronil, *The Magical State: Nature, Money, and Modernity in Venezuela* (Chicago, 1997), 26–27; John Bellamy Foster, "Marx's Theory of Metabolic Rift: Classical Foundations for Environmental Sociology," *American Journal of Sociology* 105, no. 2 (1999): 366–405; and Jason W. Moore, "Environmental Crises and the Metabolic Rift in World-Historical Perspective," *Organization & Environment* 13, no. 2 (2000): 123–157.

[28] Victor Hugo, as quoted in Sabine Barles and Laurence Lestel, "The Nitrogen Question: Urbanization, Industrialization, and River Quality in Paris," *Journal of Urban History* 33, no. 5 (2007): 794–812, here 799.

[29] W. W. Carpenter, "Sanitary and Economical Use of Night-Soil in Paris," *The California Agriculturalist*, July 1, 1874, 157. For more on European evaluations of urban nutrient reuse, see Erland Mårald, "Everything Circulates: Agricultural Chemistry and Recycling Theories in the Second Half of the Nineteenth Century," *Environment and History* 8, no. 1 (2002): 65–84.

[30] Examples of the metabolic metaphor in urban history include Maria Kaïka, *City of Flows: Modernity, Nature, and the City* (New York, 2005); Matthew Gandy, *Concrete and Clay: Reworking Nature in New York City* (Cambridge, Mass., 2002); Joel A. Tarr, "The Metabolism of the Industrial City: The Case of Pittsburgh," *Journal of Urban History* 28, no. 5 (2002): 511–545; J. R. McNeill, *Something New under the Sun: An Environmental History of the Twentieth Century* (New York, 2000), 269–295; and William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York, 1991).

[31] Steven Stoll, *Larding the Lean Earth: Soil and Society in Nineteenth Century America* (New York, 2002), 49.

Applications to Agriculture and Physiology, he ushered in an era of scientific farming. As Liebig contended, "It must be admitted as a principle of agriculture, that those substances which have been removed from a soil must be completely restored to it . . . A time will come when the fields will be manured with a solution of glass (silicate of potash), with the ashes of burnt straw, and with salts of phosphoric acid, prepared in chemical manufactories, exactly as present medicines are given for fever and goiter."[32] If soil exhaustion was the ailment, Liebig's remedy was neither cow dung nor clover, but rather a potent manufactured combination of chemical fertilizers.[33]

One year after Liebig's monumental work appeared, French scientist Alexandre Cochet published the results of his experiments on guano from the Chincha Islands. The Chinchas, three granite islands located 13 miles (21 kilometers) off the southwest coast of Peru, were covered in guano from the Guanay cormorant (*Phalacrocorax bougainvillii*), the Peruvian booby (*Sula variegate*), and the Peruvian brown pelican (*Pelicanus occidentalis thagus*), which feed on the anchovetas (*Engraulis ringens*) and Pacific sardines (*Sardinops sagax*) that thrive in the cold, nutrient-rich waters of the Humboldt Current. Because the Peruvian coast is among the driest places on earth, there was rarely enough rainfall to dissolve the accumulated excrement. Over many millennia, these chalky deposits became fossilized storehouses of nitrogen, phosphates, and alkaline salts.[34]

Centuries before Francisco Pizarro's conquest of Peru (1531–1533), the Quechua-speaking farmers of the region had raised the yields of their coastal maize crops with regular applications of guano. In his 1609 *Comentarios reales de los Incas*, Garcilaso Inca de la Vega recalled, "On the sea coast, from below Arequipa to Tarapaca, a distance of more than two hundred leagues, they use no other manure than the droppings of sea birds, of which there are large and small along all the coast, and they fly in such enormous flocks that it would be incredible to any one who had not seen them. They breed on certain desert islands on the coast, and the quantity they make is also incredible. From a distance these heaps of manure look like the peaks

[32] Justus von Liebig, *Organic Chemistry in Its Applications to Agriculture and Physiology*, in Liebig, *Liebig's Complete Works on Chemistry*, ed. Lyon Playfair (Philadelphia, 1852), 63. Benjamin R. Cohen has offered a nuanced account of how soil science became "culturally credible" in the antebellum United States, emphasizing the gradual and contested nature of this process; Cohen, *Notes from the Ground: Science, Soil and Society in the American Countryside* (New Haven, Conn., 2009), x.

[33] To his credit, Liebig was deeply critical of the British for importing guano while simultaneously flushing nutrient-rich human excrement to the sea. See Justus von Liebig, *Familiar Letters: In Its Relations to Physiology, Dietetics, Agriculture, Commerce, and Political Economy*, 3rd ed. (London, 1851), 473. British scientists Sir John Bennett Lawes and Sir Joseph Henry Gilbert, who co-founded the Rothamstead Research Station in Hertfordshire, were also fundamental to the development of fertilizer science. In 1843, Lawes patented a process for decomposing bones with sulfuric acid to create the superphosphates that British farmers applied in copious quantities to their fields. For more on agricultural innovations before the rise of formal soil chemistry, see Wallace E. Huffman and Robert E. Evenson, *Science for Agriculture: A Long-Term Perspective* (Ames, Iowa, 1993), 15. North American farmers had access to summaries of Liebig's findings almost immediately in the agricultural press. See, for example, "Notice of Liebig's Organic Chemistry, Applied to Agriculture," *The Cultivator* 8 (May 1841): 73–75.

[34] On the guano birds and their relationship to the Humboldt Current, see the essays in D. Pauly and I. Tsukayama, eds., *The Peruvian Anchoveta and Its Upwelling Ecosystem: Three Decades of Change* (Callao, Peru, 1987). For a discussion of the relationship between guano bird productivity and El Niño events, see Brian Fagan, *Floods, Famines, and Emperors: El Niño and the Fate of Civilizations* (New York, 1999), chap. 2. Among the most comprehensive scientific works on guano is G. Evelyn Hutchinson, *The Biogeochemistry of Vertebrate Excretion* (New York, 1950).

of snowy mountains."[35] Despite such astounding claims, Garcilaso's observations went unheeded for two centuries.

It was not until Prussian naturalist Alexander von Humboldt spent the years from 1799 to 1804 in the Americas that Europe's chemists and agronomists took notice of Pacific Coast fertilizers. In 1802, while visiting the Peruvian port city of Callao, Humboldt (after whom the northwesterly Pacific current takes its name) explored guano's growth-promoting properties. Upon his return to Europe, he shared his findings with his colleagues and sparked a new interest in the Peruvian product. By the 1820s, North American agricultural journals were informing their readers of Peru's soil-enhancing bird dung.[36]

Like Humboldt, French mining engineer Jean Baptiste Boussingault traveled extensively throughout South America, living there for more than a decade. He visited Peru's northern harbor of Paita in 1832 and remarked, "Along a great extent of the coast of Peru, the soil, which is perfectly barren of itself is rendered fertile, and is made to yield abundant crops, by the application of guano."[37] Once soil scientists endorsed guano, the next step for eager commercial interests was to organize the means of extracting the foul-smelling product for export from the Pacific coast to Atlantic ports.

Thousands of Chinese debt peons, known colloquially as *colonos asiáticos* (Asian settlers), undertook the task of digging seabird feces. In the 1840s, capitalists and their state sponsors began relying on the coolie trade for cheap, unskilled labor. British imperial officials orchestrated the sea change from the transatlantic slave trade to the transpacific traffic in debt peons. Nominally, Chinese migration followed the imperatives of "free labor," or contractual wage work with the "freedom" to quit. British Foreign Secretary Lord John Russell underscored this notion. On July 11, 1860, he contended that his country's encouragement of the coolie trade represented a decisive stand for abolitionism and free labor: "Her Majesty's government, therefore proposes, with a view to the final extinction of the Slave Trade . . . a plan of emigration from China regulated by agents of the European nations in conjunction with the Chinese authorities."[38] Despite Russell's rhetoric, countless testimonials concerning the brutal realities of transpacific debt peonage contradicted such emancipatory claims.[39]

[35] Garcilaso Inca de la Vega was the son of Spanish conquistador Sebastián Garcilaso de la Vega and the Inca princess Isabel Suárez Chimpu Ocllo. The stories Garcilaso related in the *Comentarios* are tales he heard as a child growing up in Cuzco. Garcilaso Inca de la Vega, *First Part of the Royal Commentaries of the Yncas*, trans. Clements R. Markham, 2 vols. (1609; repr., New York, 1963), 2: 11. For other examples of early European interest in guano, see Amédée François Frézier, *A Voyage to the South-Sea, and along the Coasts of Chile and Peru, in the Years 1712, 1713, and 1714* (London, 1717); and Jorge Juan and Antonio de Ulloa, *A Voyage to South America*, trans. John Adams (1807; repr., Boston, 1978).

[36] Arthur P. Whitaker, "Alexander von Humboldt and Spanish America," *Proceedings of the American Philosophical Society* 104, no. 3 (1960): 317–322, here 321; and "Guano—A Celebrated Manure Used in South America," *American Farmer* 6 (December 1824): 316–317.

[37] Jean Baptiste Boussingault, *Rural Economy, in Its Relation with Chemistry, Physics, and Meteorology; or, Chemistry Applied to Agriculture*, trans. George Law (New York, 1850), 255.

[38] Lord John Russell, as quoted in Meagher, *The Coolie Trade*, 39.

[39] On the disparity between the British government's attitude toward African slavery in the Atlantic

"Vessels, it appears, are equipped for the business upon the model of slave ships," explained a *New York Daily Times* correspondent in 1853 when describing the ships transporting Chinese workers to Peru. "The victims—men, and even children—are kidnapped. They are crowded down between low decks, where any other than a prone or sitting posture is out of the question."[40] One in every ten of these men and boys died during the grueling journey, while those who survived ended up on Peru's coastal plantations or spent countless years shoveling guano.[41]

Guano excavation ranked among the world's deadliest and least remunerative jobs. Contractors demanded that each worker mine a quota of four tons per day for the meager wage of three *reales*, or seven pesos, per month.[42] As an English observer was appalled to find, "During the last quarter of 1875, it is reported that there were 355 Chinamen employed [on one of the Chincha Islands], of whom no less than 98 were in the hospital. The general sickness is swelled legs, caused, it is supposed, by drinking condensed water not sufficiently cooled, and by a lack of vegetable diet."[43] In addition, the ammonia-laden guano dust triggered devastating ailments in the lungs of those who constantly breathed the foul-smelling, acrid powder. Such horrendous conditions led to drastic measures; suicide among guano workers was so common that notices of its occurrence appeared regularly in *El Commercio* and *El Nacional*, Peru's leading nineteenth-century newspapers.[44]

Guano mining was rarely mechanized. As of 1853, two steam shovels operated on the north island of the Chinchas, but manual labor persisted.[45] George Wash-

world and forms of debt peonage in the Pacific world, see Lawrence Phillips, "British Slavery after Abolition: The Pacific Trade," *Race & Class* 41, no. 3 (2000): 13–27.

[40] "The Asiatic Slave Trade," *New York Daily Times*, July 22, 1853, 4.

[41] Carlos Contreras and Marcos Cueto, *Historia del Perú contemporáneo: Desde las luchas por la Independencia hasta el presente*, 2nd ed. (Lima, 2000), 127–136; Michael J. Gonzales, *Plantation Agriculture and Social Control in Northern Peru, 1875–1933* (Austin, Tex., 1985), esp. chap. 5; and Jonathan V. Levin, *The Export Economies: Their Pattern of Development in Historical Perspective* (Cambridge, Mass., 1960), 85–90, 130–132. The most comprehensive study of Chinese coolie laborers on Peruvian cotton and sugar plantations is Humberto Rodríguez Pastor, *Hijos del Celeste Imperio en el Perú (1850–1900): Migración, agricultura, mentalidad y explotación* (Lima, 1990). The Chinese migration to Peru was overwhelmingly male. The incomplete Peruvian census of 1872 lists 12,849 Chinese living in the four coastal provinces of Lamabayeque, Chiclayo, Trujillo, and Pacsamayo. Of those, only 15 were women. See the Censo de 1872, Archivo General de Peru, as cited in Evelyn Hu-DeHart, "Latin America in Asia-Pacific Perspective," in Rhacel S. Parreñas and Lok C. D. Siu, eds., *Asian Diasporas: New Formations, New Conceptions* (Stanford, Calif., 2007), 58 n. 3.

[42] Nicolás de Piérola, *Informe sobre el estado del carguío de huano en las Islas de Chincha, y sobre el cumplimiento del contrato celebrado con D. Domingo Elías* (Lima, 1853), 4; and Antonio Raimondi, *Informes y polémicas sobre el guano y el salitre (Perú 1854–1877)* (Lima, 2003), 64. For a detailed discussion of wage rates on the Chinchas, see W. M. Mathew, "A Primitive Export Sector: Guano Production in Mid-Nineteenth-Century Peru," *Journal of Latin American Studies* 9, no. 1 (1977): 35–57, here 47–48.

[43] Fitz-Roy Cole, as quoted in Stewart, *Chinese Bondage in Peru*, 97. Among the most comprehensive sources on guano island labor is Cecilia Méndez G., *Los trabajadores guaneros del Perú, 1840–1879* (Lima, 1987).

[44] Vivid firsthand testimonials about the horrifying stench of the Chinchas can be found in the account of French engineer André Bresson, *Bolivia: Sept années d'explorations, de voyages et de séjours dans l'Amérique australe* (Paris, 1886), 348–349; and George W. Peck, *Melbourne, and the Chincha Islands: With Sketches of Lima, and a Voyage round the World* (New York, 1854), 211.

[45] Peter Blanchard, "The 'Transitional Man' in Nineteenth-Century Latin America: The Case of Domingo Elias of Peru," *Bulletin of Latin American Research* 15, no. 2 (1996): 157–176; and Mathew, "A Primitive Export Sector," 49. Although William S. Otis patented the steam shovel in 1839, his machines were cumbersome; few excavators used them until the 1880s. See Samuel Stueland, "The Otis

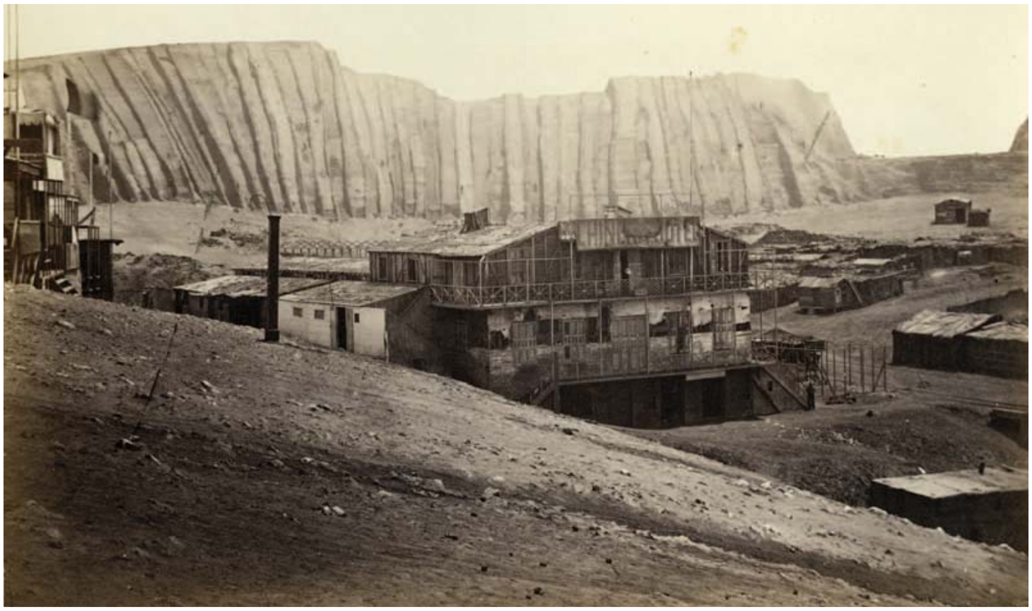

FIGURE 1: Guano Mining Operations on Peru's Chincha Islands in 1862. Note workers' quarters in the foreground and mined cliffs of guano in the background. Albumen print, photographer unknown. Courtesy of the New Bedford Whaling Museum, New Bedford, Mass.

ington Peck, who sailed from Australia to Peru in 1853, described how Chinese workers conveyed the guano to waiting ships: "Coolies, who are obliged to wear thick bandages over their mouths, push the guano down to the lower ends of the mangueras [hoses], where there are openings connected with 'shutes,' or long canvas pipes, about as large [a]round as barrels, that lead down to the bases of the cliff. Through these the guano is conducted into launches, or directly into the holds of vessels loading."[46] On the receiving end, deckhands risked being sucked into the avalanche of powder. As a Yankee captain related to the *Providence Journal*, "Cases have occurred where men have slipped in at the mouth of the hose as the guano went in or down, and were never seen again, or dead, if found at all."[47] Burial at sea had never implied such a dreadful fate.

As ships laden with guano departed the Chinchas, boats crammed with Chinese laborers arrived to replace deceased or terminally ill miners. The coolie trade between China and Peru was big business. Recognizing this, the leading inter-American shipping house of W. R. Grace and Company sought to expand its enterprises by transporting debt peons. William Russell Grace wrote to his brother Michael in the early 1870s, "There is lots of money in the business. 600 men in China costs [*sic*] $60,000." After coldly calculating a 10 percent death rate during the transpacific

Steam Excavator," *Technology and Culture* 35, no. 3 (1994): 571–574, here 572, 574. The availability of Chinese debt peons may be one reason that a Peruvian mining proletariat did not emerge until the 1890s. On this point, see Josh DeWind, *Peasants Become Miners: The Evolution of Industrial Mining Systems in Peru* (New York, 1987), esp. chap. 1.

46 George Washington Peck, as quoted in Robert Cushman Murphy, *Bird Islands of Peru: The Record of a Sojourn on the West Coast* (New York, 1925), 112.

47 Captain Congdon, as quoted in *Debow's Review* 16 (January 1854): 100.

passage, William continued, "that cargo of 540 men can be sold the moment they are shipped [at] $340 hard dollars each or say $183,660."[48] This lucrative trade in human cargoes centered on Macao, where Portuguese merchants organized the recruitment process that bound coolies to employers across the Pacific. Crimping and kidnapping were common means of supplementing more formal contractual arrangements, and many coolies found themselves "inveigled to the islands . . . under specious promises."[49]

The number of coolies who made up the guano labor force is notoriously difficult to ascertain. During the early 1840s, Peruvian convicts and army deserters supplied most of the labor for guano extraction, but in October 1849, the first Chinese workers arrived aboard the Danish ship *Frederick William*. An account from 1853 registered 1,000 miners, most of them from China, toiling on the Chinchas. Initially, two plantation owners, Domingo Eliás and Juan Rodríguez, held exclusive government licenses for the introduction of coolies to the guano mines and coastal farms of Peru. Under their control, conditions remained abominable. A visitor to the islands wrote in 1853, "The Chinese work almost naked under a tropical sun where it never rains. They are slender figures and do not look strong."[50] Abuses proved so outrageous that an international outcry prompted the Peruvian government to suspend the coolie trade in 1856. The government then reopened it in 1861. Finally, on July 26, 1874, representatives of the Chinese and Peruvian governments signed the Tratado de paz, amistad, comercio y navegación [Treaty of Peace, Friendship, Commerce and Navigation], which promoted Chinese commercial activities in Peru and encouraged movement of the labor trade away from guano digging and plantation labor and toward mainland mining operations and railroad work. All told, as many as 10,000 Chinese coolies may have dug guano on the Chincha Islands during the mid-1800s.[51]

The Chinese bound for Peru resisted the cruel strictures of debt peonage, refusing to wait for long-overdue government assistance from imperial officials in distant Beijing. Resistance often took the form of rebellion during the Pacific crossing.

[48] William R. Grace, as quoted in C. Alexander G. de Secada, "Arms, Guano, and Shipping: The W. R. Grace Interests in Peru, 1865–1885," *Business History Review* 59, no. 4 (1985): 597–621, here 608.

[49] On the coolie trade from Macao, see Stewart, *Chinese Bondage in Peru*, 17. Quote from "The Chincha Islands," *Nautical Magazine and Naval Chronicle*, April 1856, 182. In 1862, the Peruvian government granted labor contractor Andres Calderón a license to recruit 800–1,000 Hawaiians and Polynesians to dig guano on the Chinchas. See Juan de Arona, *La inmigración en el Perú: Monografía histórico-crítica* (Lima, 1891), 86–88. Henry Evans Maude contends that the project failed to bring any of these Pacific Islanders to the Chinchas; Maude, *Slavers in Paradise: The Peruvian Slave Trade in Polynesia, 1862–1864* (Stanford, Calif., 1981), 136.

[50] "Letter from the Chincha Islands," as quoted in Meagher, *The Coolie Trade*, 227.

[51] For numbers of workers on the Chinchas, see Levin, *The Export Economies*, 88; Meagher, *The Coolie Trade*, 224; and Stewart, *Chinese Bondage in Peru*, 96. On the contracts granted to Eliás and Rodríguez, see Evelyn Hu-Dehart, "Coolies, Shopkeepers, Pioneers: The Chinese of Mexico and Peru (1849–1930)," *Amerasia* 15, no. 2 (1989): 91–116, here 103. As of 1909, the Peruvian government limited Chinese immigration to relatives of Peruvian residents. By 1934, Peru had barred all Chinese entry. See Ayumi Takenaka, "The Japanese in Peru: History of Immigration, Settlement, and Racialization," *Latin American Perspectives* 31, no. 3 (2004): 77–98, here 87; and Bernard Wong, "A Comparative Study of the Assimilation of the Chinese in New York City and Lima, Peru," *Comparative Studies in Society and History* 20, no. 3 (1978): 335–358. The text of the treaty appears in Ministerio de Relaciones Exteriores, *Coleccion de los tratados del Perú* (Lima, 1876), 159–165. After the expiration of their indenture contracts, many Chinese migrants who came to Peru's coastal plantations and guano mines settled in Lima, where they established a thriving Chinatown known as the Barrio Chino. See, for example, Isabelle Lausent-Herrera, "The Chinatown in Peru and the Changing Peruvian Chinese Community(ies)," *Journal of Chinese Overseas* 7, no. 1 (2011): 69–113.

As Basil Lubbock remarked, "a rising of the coolies was the one terror that ever stalked behind the captain of a Chinese coolie ship. In order to prevent the ships from being captured by their passengers, the decks and hatchway openings were barred and barricaded like the old convict ships."[52] Attempts at physical confinement proved unsuccessful; no fewer than sixty-eight coolie ships experienced mutinies between 1847 and 1874.[53]

For guano merchants, however, lucrative ends justified horrifying means. Between 1840 and 1878, Peruvian guano exports surpassed 12.6 million metric tons (see Figure 2), garnering $750 million. Monetary sums of this magnitude were rare in the nineteenth century; justifiably, this period was known as Peru's "Guano Era."[54]

Few Peruvians benefited from the guano trade, however. Under the "consignment system," their government auctioned off the extraction rights and marketing privileges to private mercantile houses in exchange for loans based on future profits. The British companies W. J. Meyers of Liverpool and Anthony Gibbs & Sons of London dominated the guano trade in the mid-1800s. A popular London rhyme of the period went: "The House of Gibbs made their dibs selling the turds of foreign birds."[55] Guano profits financed the construction of lavish British estates, including the Gothic Revival mansion of Tyntesfield in North Somerset near Bristol.[56]

Between 1841 and 1857, Britain imported 2.4 million metric tons of guano, which farmers used to fertilize crops of wheat, hops, and turnips. By 1846, the editors of the *Journal of Agriculture* commented, "Guano is now so well known as an excellent promoter of green crops, that its use may be said to be firmly established in the husbandry of this country."[57] These nutrient-rich infusions produced wondrous results. British parliamentarian and agricultural journalist Chandos Wren Hoskyns praised guano as "The Wizard of the Pacific," while the Scottish writer William Wallace Fyfe contended in 1859, "Guano is, probably, the animal manure most justly

[52] Basil Lubbock, *Coolie Ships and Oil Sailers* (Glasgow, 1935), 33.

[53] Meagher, *The Coolie Trade*, 191.

[54] These calculations are based on data from Shane J. Hunt, *Price and Quantum Estimates of Peruvian Exports, 1830–1962* (Princeton, N.J., 1973), 57–59; Antonio Raimondi, "Islas, islotes y rocas del Perú," *Boletín de la Sociedad Geográfica de Lima* 7 (1897): 278–289; Heraclio Bonilla, *Guano y burguesia en el Perú* (Lima, 1974); and Paul Gootenberg, *Imagining Development: Economic Ideas in Peru's "Fictitious Prosperity" of Guano, 1840–1880* (Berkeley, Calif., 1993), 2. As Gootenberg notes, until the 1860s, the Peruvian peso and the U.S. dollar were equal in monetary value. To put the $750 million figure in relative perspective, one estimate suggests that California's gold exports between 1848 and 1860 totaled $650 million. See Larry Schweikart and Lynne Pierson Doti, "From Hard Money to Branch Banking: California Banking in the Gold-Rush Economy," in James J. Rawls and Richard J. Orsi, eds., *A Golden State: Mining and Economic Development in Gold Rush California* (Berkeley, Calif., 1999), 209–232, here 212.

[55] James Higgins, *Lima: A Cultural History* (New York, 2005), 113.

[56] W. M. Mathew, *The House of Gibbs and the Peruvian Guano Monopoly* (London, 1981). Texts of the actual contracts appear in P. Emilio Dancuart, ed., *Anales de la hacienda pública de Perú: Historia y legislación fiscal de la república*, 24 vols. (Lima, 1902–1926), 5: 23–25. In 1869, Peru abandoned the consignment system when it contracted with the Paris-based firm Dreyfus Brothers & Co. to sell two million tons of guano on the European market. On Dreyfus Brothers & Co., see Levin, *The Export Economies*, 98–99. For more on how Peru serviced its foreign debt with guano profits, allowing it to sustain its credit rating despite domestic political upheavals, see Catalina Vizcarra, "Guano, Credible Commitments, and Sovereign Debt Repayment in Nineteenth-Century Peru," *Journal of Economic History* 69, no. 2 (2009): 358–387; and Peter F. Klaren, "The Sugar Industry in Peru," *Revista de Indias* 65, no. 233 (2005): 33–48, here 36–37.

[57] "Plan for Reducing the Price of Guano Twenty-Five Per Cent," *Journal of Agriculture* 2 (July 1846): 386.

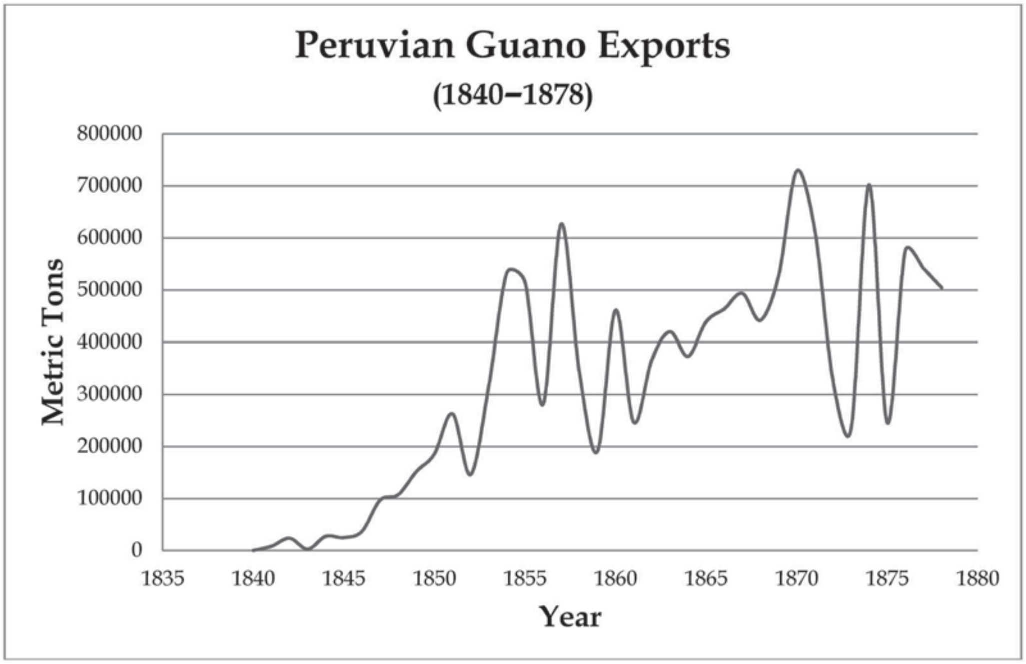

FIGURE 2: *Sources*: Shane J. Hunt, *Price and Quantum Estimates of Peruvian Exports, 1830–1962* (Princeton, N.J., 1973), Table 21; José Antonio de Lavalle y García, *El guano y la agricultura nacional* (Lima, 1914), 41; Antonio Raimondi, "Islas, islotes y rocas del Perú," *Boletín de la Sociedad Geográfica de Lima* 7 (1897): 278–289; Heraclio Bonilla, *Guano y burguesia en el Perú* (Lima, 1974), 131–132; and Richard Webb and Graciela Fernández Baca de Valdez, eds., *Almanaque estadístico: Perú en números 1990* (Lima, 1990), 388. *Note:* During the War of the Pacific (1879–1883), Chile occupied Peru's guano islands.

in vogue in agriculture."[58] Unlike calcareous fertilizers, such as lime, gypsum, and marl, Peruvian bird excrement possessed the natural advantage of smelling like cow manure, which made it more acceptable to farmers. One British agriculturalist even recommended tasting it for definitive proof of this similitude.[59]

British merchants also sold Peruvian guano to other nations, helping French and Prussian sugar beet farmers ease European dependence on Caribbean sugarcane imports. By 1860, Prussia switched from being a net sugar importer to being a net sugar exporter.[60] As a high-ranking Prussian Ministry of Agriculture official recalled, the mid-nineteenth century "was a time in which we believed that there was no limit to the increase of [sugar beet] yields thanks to the ever growing availability of cheap commercial fertilizers."[61] Similarly, farmers in the Netherlands conducted extensive

[58] Chandos Wren Hoskyns, *Talpa; or, The Chronicles of a Clay Farm*, 2nd ed. (Buffalo, N.Y., 1854), 90; William Wallace Fyfe, *Agricultural Science Applied in Practice* (London, 1859), 129.

[59] On guano and hop cultivation in Britain, see Celia Cordle, "The Guano Voyages," *Rural History* 18, no. 1 (2007): 119–133. The guano-tasting suggestion can be found in Thompson, "The Second Agricultural Revolution," 70. For an overview of the British demand for guano, see W. M. Mathew, "Peru and the British Guano Market, 1840–1870," *Economic History Review* 23, no. 1 (1970): 112–128.

[60] Wilhelm Ruprecht, "The Historical Development of the Consumption of Sweeteners—A Learning Approach," *Journal of Evolutionary Economics* 15, no. 3 (2005): 247–272, here 254.

[61] Hugo Thiel, as quoted in Thomas Wieland, "Scientific Theory and Agricultural Practice: Plant Breeding in Germany from the Late 19th to the Early 20th Century," *Journal of the History of Biology* 39, no. 2 (2006): 309–343, here 314. During the Meiji Period (1868–1912), Japanese farmers became increasingly reliant on inputs of purchased fertilizers. Often these included herring fishmeal and guano

experimentation with Peruvian guano, and Dutch imports of the South American fertilizer grew by at least 7,000 metric tons per year during the period from 1865 to 1874.[62]

In the United States, Peruvian guano came to symbolize progressive agricultural practices. Its fertilizing prowess received glowing endorsements from leading agricultural journals of the day, including the *Farmers' Register*, the *Southern Cultivator*, and the *Farmer's Journal*. In 1853, a North Carolina farmer told the *Farmer's Journal* that "There are many rich fields in many parts of the country, which but for guano would have still been barren, failing to produce enough to pay the owner for their cultivation." The Peruvian fertilizer fueled bumper harvests of tobacco and cotton across the South.[63]

Because of guano's recognized effectiveness, its price rose dramatically in the United States after it was first used in the 1840s. In 1843, a shipload of guano arrived in Baltimore and fetched $.07 a ton. Seven years later, the price hit $76 per ton, eventually leveling out at $50 per ton. Between 1860 and 1880, farmers throughout North and South Carolina, Georgia, Maryland, and Virginia expended a combined sum of $14,094,000 on commercial fertilizer.[64]

High guano prices triggered anxiety among the cultivators who opted to invest in fertilizer supplements. American farmers soon began insisting that the federal government break Peru's "guano monopoly."[65] President Millard Fillmore made guano acquisition a central foreign policy concern. In his first annual message, delivered on December 2, 1850, he announced, "Peruvian guano has become so de-

collected from neighboring Pacific islands. It remains unclear whether the Japanese ever imported Peruvian guano. See Mataji Miyamoto, Yōtarō Sakudō, and Yasukichi Yasuba, "Economic Development in Preindustrial Japan, 1859–1894," *Journal of Economic History* 25, no. 4 (1965): 541–564, here 562; and Bruce F. Johnston, "Agricultural Productivity and Economic Development in Japan," *Journal of Political Economy* 59, no. 6 (1951): 498–513, here 506. See also Nagahisa Kuroda, "Report on a Trip to Marcus Island with Notes on the Birds," *Pacific Science* 8, no. 1 (1954): 84–93.

62 Merijn T. Knibbe, "Feed, Fertilizer, and Agricultural Productivity in the Netherlands, 1880–1930," *Agricultural History* 74, no. 1 (2000): 39–57, here 46.

63 Quote from Weymouth T. Jordan, "The Peruvian Guano Gospel in the Old South," *Agricultural History* 24, no. 4 (1950): 211–221, here 219. For other examples, see A. MacDonald, "Results from Guano Manure," *Farmers' Register: A Monthly Publication* 9, no. 12 (1841): 735–736; and Solon Robinson, "How to Use Guano," *Southern Cultivator* 9, no. 5 (1851): 70–71, here 70.

64 Wines, *Fertilizer in America*, 39; Chester McArthur Destler, "David Dickson's 'System of Farming' and the Agricultural Revolution in the Deep South, 1850–1885," *Agricultural History* 31, no. 3 (1957): 30–39, here 32; Wayne D. Rasmussen, "The Impact of Technological Change on American Agriculture, 1862–1962," *Journal of Economic History* 22, no. 4 (1962): 578–591, here 580; and John Solomon Otto, *Southern Agriculture during the Civil War Era, 1860–1880* (Westport, Conn., 1994), 84. In 1897, Benjamin William Arnold claimed that guano had played a major role in the cultivation of bright yellow tobacco in the border counties of Virginia and North Carolina; Arnold, *History of the Tobacco Industry in Virginia from 1860 to 1894* (Baltimore, 1897), 24 n. 1. For accounts of guano use on the Tidewater tobacco plantations along the Chesapeake Bay, see Solon Robinson, *Guano: A Treatise of Practical Information for Farmers* (New York, 1853), 13; and William L. Bradley, *Bradley's Manual on Growing and Curing Tobacco* (Boston, 1864), 18–19.

65 Jordan, "The Peruvian Guano Gospel in the Old South," 216. For guano prices, see also Rosser H. Taylor, "The Sale and Application of Commercial Fertilizers in the South Atlantic States to 1900," *Agricultural History* 21, no. 1 (1947): 46–52, here 47, 50. On the role of guano in the agricultural practices of the antebellum South, see Eugene D. Genovese, *The Political Economy of Slavery: Studies in the Economy and Society of the Slave South*, 2nd ed. (Middletown, Conn., 1989), 92–94.

sirable an article to the agricultural interest of the United States that it is the duty of the Government to employ all means properly in its power for the purpose of causing that article to be imported into the country at a reasonable price. Nothing will be omitted on my part toward accomplishing this desirable end."[66] The passage of the Guano Islands Act of 1856, which legalized the private appropriation of unclaimed guano islands in the name of the United States, signaled the urgency with which legislators pursued the procurement of organic fertilizer: "Whenever any citizen of the United States discovers a deposit of guano on any island, rock, or key, not within the lawful jurisdiction of any other Government, and not occupied by the citizens of any other Government, and takes peaceable possession thereof, and occupies the same, such island, rock, or key may, at the discretion of the President, be considered as appertaining to the United States."[67]

Yet such far-reaching mandates proved superfluous. During the late 1870s, as Peru's guano supplies began to dwindle, excitement shifted to the fertilizing potential of sodium nitrate.[68] In 1877, the *Saturday Evening Post* published a story titled "Immense Nitre Deposits, Which Will Prove of More Value Than Guano."[69] That same year, the editors of the Atlanta farm journal *Southern Cultivator* wrote of nitrate of soda, "Few fertilizers act so rapidly when judiciously applied."[70] Professor Mason Graham Ellzey of the Virginia Agricultural and Mechanical College wrote to Baltimore's *American Farmer* to recommend that farmers use nitrate of soda because "Wheat following corn, or even tobacco, must have artificial supplies of nitrogen, or a maximum crop cannot be made. The feeding of stock on the field for a few months before the corn is planted, gives the land some nitrogen, but certainly much less than is provided in 100 lbs. per acre of nitrate of soda and less than is removed by the corn."[71] One reason for the popularity of sodium nitrate fertilizer was that it dis-

[66] James D. Richardson, *A Compilation of the Messages and Papers of the Presidents, 1789–1897*, 10 vols. (Washington, D.C., 1896–1899), 5: 83.

[67] U.S. Code, Title 48, Chapter 8, Section 1411. The whole act is covered in sections 1411–1419. On the legal history of the guano islands claimed by U.S. citizens, see Christina Duffy Burnett, "The Edges of Empire and the Limits of Sovereignty: American Guano Islands," *American Quarterly* 57, no. 3 (2005): 779–803. For more on the Guano Islands Act and U.S. imperialism, see Jimmy M. Skaggs, *The Great Guano Rush: Entrepreneurs and American Overseas Expansion* (New York, 1994). In March 1843, British merchants began exploiting guano on Ichaboe Island, which lies off the coast of present-day Namibia. Excavating the West African deposit was a short-lived venture. Ichaboe's total guano reserves were only 300,000 metric tons, half of the total product coming out of Peru on an annual basis in the 1860s. Within three years, Ichaboe's deposits were totally depleted. Benjamin L. Turner, Emmanuel Frossard, and Darren S. Baldwin, eds., *Organic Phosphorus in the Environment* (Cambridge, Mass., 2005), 51. In 1857, the U.S. took possession of Navassa, a small island situated between Haiti and Jamaica. In 1889, African American guano diggers on Navassa revolted against their bosses and killed five white supervisors. For an account of this uprising and its aftermath, see Jennifer C. James, "'Buried in Guano': Race, Labor, and Sustainability," *American Literary History* 24, no. 1 (2012): 115–142; and John Cashman, "'Slaves under Our Flag': The Navassa Island Riot of 1889," *Maryland Historian* 24, no. 2 (1993): 1–21.

[68] In 1860, a Chilean named José Santos Ossa discovered the *salitre* deposits in Antofagasta. See Julio H. Iglesias, *José Santos Ossa: Perfiles de un conquistador, biografía* (Santiago, 1945). Peru revived its guano trade in the twentieth century. See Gregory T. Cushman, "'The Most Valuable Birds in the World': International Conservation Science and the Revival of Peru's Guano Industry, 1909–1965," *Environmental History* 10, no. 3 (2005): 477–509.

[69] "Immense Nitre Deposits," *Saturday Evening Post*, November 24, 1877, 3.

[70] "Nitrate of Soda," *Southern Cultivator* 35 (September 1877): 348.

[71] M. G. Ellzey, "Nitrogen and Phosphates," *American Farmer (Baltimore)* 3 (September 1, 1884): 237.

solved easily in water, making its nitrogen readily available to plant roots shortly after application.[72]

UNTIL 1879, THE NITRATE TRADE involved Bolivia, Peru, and Chile. During the War of the Pacific (1879–1883), Chile defeated the allied forces of Peru and Bolivia. With the 1883 Treaty of Ancón, Chile acquired the provinces of Tarapacá, Tacna, and Arica. Additionally, Bolivia forfeited its coastal access when it ceded the Pacific seaport of Antofagasta to Chile in 1884. Thus, Chile won exclusive control over the valuable nitrate mines in the northern Atacama Desert, which extended 400 miles (644 kilometers) from north to south.[73]

In the parched sands of the Atacama, a crucial element of life abounded. Sodium nitrate (*salitre*) contains approximately 16 percent nitrogen and 27 percent sodium. Nearly all of the mined sodium nitrate in the world originates from deposits in the deserts of northwestern South America, where it occurs in a mixture with other salts, such as potassium nitrate, and assorted trace metals, iodine, and insoluble compounds. The most nitrogen-rich form of extractable nitrate is known as *caliche*, a calcite-bound layer of rock found beneath several meters of gravel and powdered composites. Miners (*calicheros*) worked for nitrate refineries (*oficinas*), which were owned by wealthy Chilean *salitreros* and financed by British and American capital.

Among the most notorious captains of industry to operate in the nitrate fields was John Thomas North, an enigmatic English mechanic who began working in the *salitre oficinas* in 1871. A dozen years later, he had become the undisputed "Nitrate King," having built his fortune by supplying the parched port city of Iquique with fresh water and then using the profits from this enterprise, along with financing from a Liverpool-based merchant house, to purchase nitrate companies and railways. As one of North's detractors, the *Financial News*, quipped in 1888, "He was heard lamenting there were not more elements in nature than air, earth and water, as they were such nice things to finance."[74]

North's control of the nitrate trade was overwhelming in its scope. The flamboyant entrepreneur was either the founder or the co-founder of seventeen of the twenty-three British companies involved in the Chilean nitrate trade in 1890; thus he controlled 71 percent of an industry listed by the London Stock Exchange at a total nominal capital of £10,000,000.[75] Such colossal sums represented the value

[72] A. F. Gustafson, *Soils and Soil Management* (New York, 1941), 322.

[73] A concise summary of the war can be found in V. G. Kiernan, "Foreign Interests in the War of the Pacific," *Hispanic American Historical Review* 35, no. 1 (1955): 14–36. For a Bolivian interpretation of events, see Roberto Querejazu Calvo, *Guano, salitre, sangre: Historia de la Guerra del Pacífico* (La Paz, 1979). For a Peruvian perspective, see Heraclio Bonilla, *Un siglo a la deriva: Ensayos sobre el Perú, Bolivia y la guerra* (Lima, 1980). In 1929, the Tacna-Arica Compromise gave Arica to Chile and Tacna to Peru. Today, Chile's nitrate region extends from 19 to 26 degrees south latitude, encompassing the provinces of Tarapacá and Antofagasta. Although the combined area of the two provinces is 185,000 km^2 (comparable in size to the United Kingdom), the nitrate region occupies only 30,000 km^2 of this territory (similar in size to Belgium).

[74] Michael Monteón, "John T. North, the Nitrate King, and Chile's Lost Future," *Latin American Perspectives* 30, no. 6 (2003): 69–90. Quote from Harold Blakemore, *British Nitrates and Chilean Politics, 1886–1896: Balmaceda and North* (London, 1974), 68.

[75] William Edmundson, *The Nitrate King: A Biography of "Colonel" John Thomas North* (New York, 2011), 4. Although North's role in the Chilean civil war of 1891 is a matter of considerable debate, his

FIGURE 3: Map showing territorial changes resulting from the War of the Pacific and the 1929 Tacna–Arica Compromise. Produced by Springer Cartographics LLC for Edward D. Melillo.

extracted from years of backbreaking labor performed by Chilean, Peruvian, and Bolivian debt peons. After dislodging the *caliche* with dynamite, these workers ground it and exposed it to hot water. Using a technique called the Shanks refining process, they induced crystallization of the sodium nitrate; they then bagged the final product and sent it to coastal ports by rail.[76]

Between the 1880s and the 1930s, nitrate companies recruited miners through the *enganche* system, which involved the transportation of workers en masse to distant project sites. Prior to departure, landless peasants signed contracts, which guaranteed them a small cash advance, a wage paid in company scrip, housing, and supplies. However, this covenant also bound them to the repayment of a huge debt for their passage. Unlike the Chinese coolies who labored as single men on a bachelor frontier, many nitrate miners brought their wives and children with them to the arid landscape, where they lived in shantytowns that lacked sewers and running water. Members of these migrant families worked twelve-hour shifts under the scorching desert sun and received their pay in *fichas*, a form of scrip redeemable only at company-run stores. As a result, they had every reason to harbor bitterness toward their employers.[77]

Given such glaring class antagonisms, it is not surprising that the Atacama became a crucible of labor militancy at the beginning of the twentieth century. In the winter of 1907, 20,000 striking nitrate miners descended on Iquique, the coastal terminus of the Nitrate Railways, to demand higher wages from the powerful producers' association, the Combinación Salitrera. The Combinación refused to engage in collective bargaining with the workers, and Chilean president Pedro Montt ordered the strikers to disperse. The miners refused to disband. On December 21, government troops opened fire, killing several thousand unarmed men, women, and children who had gathered at the Santa María School. The legacy of 1907 has not been forgotten; in fact, many activists and historians consider the massacre to be the formative moment of Chile's labor movement. For others, it symbolizes the growing

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opposition to the nitrate-tax-funded public works projects of President José Manuel Balmaceda is well documented. See, for example, Maurice Zeitlin, *The Civil Wars in Chile (or the Bourgeois Revolutions That Never Were)* (Princeton, N.J., 1984). Between 1925 and 1932, the Guggenheim family was the principal foreign investor in Chile's nitrate industry. Under the military dictatorship of Carlos Ibáñez del Campo, which lasted from 1927 to 1931, the Guggenheims negotiated a corporate monopoly, COSACh (Compañía de Salitre de Chile), which became the single largest business enterprise in South America. See Thomas F. O'Brien, "'Rich beyond the Dreams of Avarice': The Guggenheims in Chile," *Business History Review* 63, no. 1 (1989): 122–159.

[76] Arvin R. Mosier, J. Keith Syers, and John R. Freney, eds., *Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment* (Washington, D.C., 2004), 234; and Eugenio Garcés Feliú, *Las ciudades del salitre: Un estudio de las oficinas salitreras en la regíon de Antofagasta* (Santiago, 1988). In 1878, James F. Humberstone, a British chemical engineer in Tarapacá, introduced the Shanks process to the sodium nitrate industry. For more on the Shanks process, see Oscar Bermúdez Miral, *Historia del salitre desde sus orígenes hasta la Guerra del Pacífico* (Santiago, 1963), 272–276. On the atmospheric origins of the sodium nitrate deposits in the Atacama Desert of Chile and the Mojave Desert of California, see J. K. Böhlke, G. E. Ericksen, and K. Revesz, "Stable Isotope Evidence for an Atmospheric Origin of Desert Nitrate Deposits in Northern Chile and Southern California, U.S.A.," *Chemical Geology* 136, nos. 1–2 (1997): 135–152.

[77] González Miranda, *Hombres y mujeres de la Pampa*, 16; William Howard Russell, *A Visit to Chile and the Nitrate Fields of Tarapaca, etc.* (London, 1890), 176–177; and Simon Collier and William F. Sater, *A History of Chile, 1808–2002*, 2nd ed. (New York, 2004), 164. Although *enganche* laborers toiled on a mining frontier, free from many of the social strictures of urban or agrarian occupations in Latin America, new regimes of control replaced those that they had left behind.

FIGURE 4: Nitrate miner (ca. 1945) at the Oficina Salitrera Victoria nitrate mines, 72 miles (115 kilometers) southeast of the city of Iquique in northern Chile. Photographer unknown. Courtesy of the University of Chile.

pains caused by a volatile mix of domestic industry and foreign imperialism. In 2005, Atacama resident Ana Benavides told a visiting North American journalist, "Chile's history is intimately linked to the nitrate story. We lived off nitrate for many years . . . It was a glorious past but it was also covered in blood."[78]

[78] On the legacies of the massacre and its place as a formative episode in the making of the Chilean working class, see Lessie Jo Frazier, *Salt in the Sand: Memory, Violence, and the Nation-State in Chile, 1890 to the Present* (Durham, N.C., 2007), 117–157; Eduardo Devés, *Los que van a morir te saludan: Historia de una masacre—Escuela Santa María de Iquique, 1907* (Santiago, 1998); and José Bengoa, "Presentación," in Crisóstomo Pizarro, *La huelga obrera en Chile* (Santiago, 1986), 5. For a more general summary of workers' movements in the *salitre* zones, see Julio Pinto Vallejos, *Trabajos y rebeldías en la pampa salitrera: El ciclo del salitre y la reconfiguración de las identidades populares (1850–1900)* (Santiago, 1998). Quote from Fiona Ortiz, "Chile's Ghost Towns Done Up for Tourists; Areas around Nitrate

Long before the Santa María massacre, the lavish lifestyles of the foreigners who ran operations in the Norte Grande had provoked working-class resentment. In Iquique, nineteenth-century travel writer Marie Robinson Wright found "clubs for gentlemen, the English Club having on its roll of membership names distinguished in the financial circles of Europe as well as America. A broad driveway along the beach connects the city with its suburb, Cavancha, a delightful resort with a dancing pavilion and promenade. A little flower garden, tended with as much solicitude as if it were a casket of jewels, gives a charming touch of natural color."[79] Exhibitions of upper-class opulence within a seemingly barren landscape were among the arresting ironies sustained by the nitrate regions.[80]

A visitor from the United States emphasized another blatant contradiction of the spatial displacements involved in the fertilizer trade: "Foodstuffs for man and beast must be imported to the nitrate region. This food problem, therefore, develops into an enormous business and might be called one of the ironies of commerce—*foodstuffs* on a large scale entering a country in order that *food-growing materials* may be sent out of a country."[81] Few examples more clearly demonstrate the global nature of the metabolic rift in modern agriculture.

Scientific experts exacerbated this split. In 1898, Sir William Crookes, president of the British Association for the Advancement of Science, stated that soil exhaustion had produced a situation in which "All England and all civilized nations stand in deadly peril of not having enough to eat."[82] Wright explained, "In suggesting a remedy, Professor Crookes recommended the use of nitrate of soda, this product forming, according to his judgment, the cheapest and most important natural source from which to derive the supplies of nitrogen necessary for the restoration of the soil."[83] Germany imported 55,000 metric tons of Chilean sodium nitrate in 1880 and achieved an average wheat output of 19 bushels per acre. In 1913, 747,000 metric tons were imported, increasing the average yield to 35 bushels per acre. That year alone, Chile exported 2.75 million metric tons of sodium nitrate.[84]

Mines Restored," *Washington Post*, November 22, 2005, A27. The December 1907 issues of *La Patria* (Iquique) offer a day-by-day account of the strike. Debt peonage arrangements in the Americas varied widely with context. As Alan Knight cautions, "The mere fact of debt, which is the overt feature of debt peonage, may thus create an illusory similitude among forms of labour which differ radically in respect of subjective conditions/perceptions and objective social implications"; Knight, "Debt Bondage in Latin America," in Léonie J. Archer, ed., *Slavery and Other Forms of Unfree Labour* (New York, 1988), 102–117, here 103. See also Arnold J. Bauer, "Rural Workers in Spanish America: Problems of Peonage and Oppression," *Hispanic American Historical Review* 59, no. 1 (1979): 34–63.

[79] Marie Robinson Wright, *The Republic of Chile: The Growth, Resources, and Industrial Conditions of a Great Nation* (Philadelphia, 1904), 270.

[80] The population explosion in the Norte Grande reflects the demographic transition sparked by the *enganche* system during the nitrate era. In 1890, fewer than 180,000 people lived in the nitrate regions, while by 1925 the population of these areas had nearly doubled, to 345,000. See John Lawrence Rector, *The History of Chile* (Westport, Conn., 2003), 125.

[81] William A. Reid, *Nitrate Fields of Chile*, 4th ed. (Baltimore, 1935), 13–15, emphasis in the original.

[82] Sir William Crookes, as quoted in Galloway and Cowling, "Reactive Nitrogen and the World," 64.

[83] Wright, *The Republic of Chile*, 282.

[84] Steven B. Webb, "Agricultural Protection in Wilhelminian Germany: Forging an Empire with Pork and Rye," *Journal of Economic History* 42, no. 2 (1982): 309–326, here 314–315; and Charles W. Bergquist, *Labor in Latin America: Comparative Essay on Chile, Argentina, Venezuela and Colombia* (Stanford, Calif., 1986), 25. Sugar beet cultivation consumed the lion's share of Europe's nitrate imports. In 1901–1902, German farmers supplied 22 percent of the world's sugar output. On nitrates and sugar

As the nitrate trade developed, it generated an increasingly complex global division of labor. Sodium nitrate shipping was one of the last enterprises to depend upon wind-powered transportation. Rival German and French builders, such as Fritz Laeisz of Hamburg and Antoine Dominique Bordes of Bordeaux, employed tens of thousands of shipyard workers in the construction of hulking five-mast, iron- and steel-hulled clipper ships, designed to carry massive cargoes of *salitre*.[85] Additionally, by the 1920s, Chile was spending more than U.S. $5,000,000 each year on jute sacks from the Bengali region in present-day Bangladesh.[86]

In the United States, sodium nitrate made its most durable contribution to a sun-drenched region in Southern California. Known as the "Inland Empire," Riverside and San Bernardino Counties became a hub of railroad commerce and a hotbed of citrus cultivation by the early 1900s. In 1890, journalist Charles Dudley Warner found that "[The city of] Riverside may without prejudice be regarded as the centre of the orange growth and trade. The railway shipments of oranges from Southern California in the season of 1890 aggregated about 2400 car-loads, or about 800,000 boxes, of oranges . . . valued at about $1,500,000."[87]

The two major varieties that filled these wooden crates were the Valencia orange and the so-called "King of Oranges," the Washington navel. British nurseryman Thomas Rivers sent Valencias from the Azores to his London greenhouses in the mid-1860s. From this stock, lawyer Alfred B. Chapman took cuttings to his estate near Los Angeles. William Saunders of the Department of Agriculture brought Washington navel oranges to the United States from Bahia, Brazil, in 1870. He planted them in Washington, D.C., and sent two specimens to Eliza Tibbets for cultivation at her new home in Riverside, California. Tibbets planted and nurtured the trees, which eventually became the source of budwood for the fledgling orange industry.[88]

Once these new cultivars took root, vast estates emerged. Archduke Ludwig Salvator of Austria saw some of these large operations when he visited Los Angeles in the winter of 1876. After touring the San Gabriel Valley by carriage, Salvator described the 1,300-acre estate of Lake Vineyard and the 500-acre estate of Mount Vineyard: "Both groves produced this year more than 1,000,000 oranges and 75,000

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beet production, see J. R. Brown, "Nitrate Crises, Combinations, and the Chilean Government in the Nitrate Age," *Hispanic American Historical Review* 43, no. 2 (1963): 230–246, here 231.

[85] For more on these vessels, see Basil Lubbock, *The Nitrate Clippers* (Glasgow, 1932).

[86] In order to protect the fledgling domestic jute industry, the Chilean government placed a duty on the re-importation of these sacks. Clarence F. Jones, "Chilean Commerce," *Economic Geography* 3, no. 2 (1927): 139–166, here 158; and Gordon T. Stewart, *Jute and Empire: The Calcutta Jute Wallahs and the Landscapes of Empire* (Manchester, 1998), 94. For details on female workers in the jute industry during the late nineteenth and early twentieth centuries, see Samita Sen, *Women and Labour in Late Colonial India: The Bengal Jute Industry* (New York, 1999).

[87] Charles Dudley Warner, *Our Italy* (New York, 1891), 119.

[88] Rahno Mabel MacCurdy, *The History of the California Fruit Growers Exchange* (Los Angeles, 1925), 5; and California State Board of Horticulture, *Culture of the Citrus in California* (Sacramento, Calif., 1900), 54.

lemons, as well as limes, olives, and walnuts."[89] Between 1880 and 1890, the number of orange trees in California increased from 1,250,000 to 3,378,000.[90]

Nitrogen deficiencies afflicted the arid regions where orange growers operated intensive irrigation systems and where a dearth of cover crops and grazing animals made legumes and manures scarce. Chilean sodium nitrate offered a convenient remedy. In 1900, one orange grower told the California State Board of Horticulture, "I bought and applied in the fall Chile saltpetre, a small amount per tree, with the evident result that I had more puffy fruit than I ever had before up to that date. I saw evident result, as the orange-growers who used it in Los Angeles County had the same experience."[91] By the mid-1920s, farmers on the Pacific Coast were applying far more Chilean sodium nitrate than their counterparts elsewhere in the United States. In 1934, the *Los Angeles Times* pointed out, "No other fruit crop in California is fertilized so heavily as are the citrus groves. Annual fertilizer expenditures of $60 per acre are common and they may be as great as $150 per acre."[92] This logic characterized the nexus of cash crop cultivation and the exotic inputs upon which it relied.[93]

It also brought fruit production into the world of commodities and their equivalencies. The *Los Angeles Times* quoted well-known horticulturalist Liberty Hyde Bailey, who had determined the amount of sodium nitrate leaving California's farms in each orange: "Figuring the percentage of nitre in each orange grown in California, Prof. Bailey estimated that there was shipped from this State last year 50,000 tons of nitre in the form of oranges."[94] Despite the usefulness of his calculations, Bailey did not quantify the years of hardship represented in each delicious fruit.

In California, as elsewhere, the First Green Revolution was linked to new labor systems and extraordinary migrations of workers. In 1939, Carey McWilliams suggested that the Golden State's bountiful harvests depended upon the wholesale exploitation of migrant Asian and Latino farmworkers, who "eke out a miserable existence, intimidated by their employers, homeless, starving, destitute. Today they are restless but quiet; tomorrow they may be rebellious."[95]

While the picture was more complicated than McWilliams suggested, his account was among the first to reveal the hidden expropriations that underwrote California's agricultural expansion. In the years that followed, these "factories in the field" expanded eastward from the Pacific Coast into North America's heartland. The Bracero Program (1942–1964) orchestrated the legally sanctioned migration of 4.6 million Mexican farmworkers to the United States.[96] Like their predecessors in the

[89] Ludwig Salvator, *Los Angeles in the Sunny Seventies: A Flower from the Golden Land*, trans. Marguerite Eyer Wilbur (Los Angeles, 1929), 156.

[90] Clifford M. Zierer, "The Citrus Fruit Industry of the Los Angeles Basin," *Economic Geography* 10, no. 1 (1934): 53–73, here 54.

[91] California State Board of Horticulture, *The Culture of the Citrus in California*, 138.

[92] Sidney B. Haskell, "Fertilizer Use in the United States," *Annals of the American Academy of Political and Social Science* 117, no. 1 (1925): 265–270, here 265–266. Quote from Zierer, "The Citrus Fruit Industry of the Los Angeles Basin," 68.

[93] On nitrogen deficiencies in citriculture, see Edward A. Ackerman, "Influences of Climate on the Cultivation of Citrus Fruits," *Geographical Review* 28, no. 2 (1938): 289–302, here 298.

[94] "Mines and Mining," *Los Angeles Times*, May, 28 1902, 11.

[95] Carey McWilliams, *Factories in the Field: The Story of Migratory Farm Labor in California* (Berkeley, Calif., 1999), 9.

[96] For a comprehensive account of the Bracero Program, see Deborah Cohen, *Braceros: Migrant*

coolie trade and the *enganche* system, these laborers worked far from home as a non-citizen underclass. Braceros and their families faced an array of challenges, including poverty wages, poor working conditions, widespread social discrimination, and a persistent shortage of social services. U.S. Labor Department official Lee Williams, who supervised the Bracero Program during its last five years, referred to it as "legalized slavery."[97]

In addition to creating an urgent problem of new seasonal labor demands, such intensifications in production required constant attentiveness to the issue of soil degradation. During the interwar years, fears of nitrate shortages caused a U.S. Department of Commerce official to assert, "The Chilean nitrate industry is a striking example of the control of a raw material by the producers thereof."[98] The "guano monopoly" was now the "nitrate monopoly." Prior to World War II, Chilean sodium nitrate accounted for 50 percent of the nitrogen used in U.S. commercial fertilizer, while globally, Chilean nitrates constituted approximately 60 percent of commercially traded nitrogen sources between 1870 and 1913. Between 1875 and 1929, Chile exported nearly 80 million metric tons of sodium nitrate.[99] *Chicago Tribune* publisher William D. Boyce was on to something when he wrote on July 23, 1911, "We Americans point with becoming pride to our great western prairies of rolling wheat lands and luxurious tracts of alfalfa and orchard country, but I think that but few of us know how much we are indebted to the nitrate workings of northern Chile."[100]

By the onset of World War I, humans had fundamentally altered the nitrogen cycle once again. On July 3, 1909, German chemist Fritz Haber informed the directors of the chemical firm Badische Anilin- und Soda-Fabrik (BASF) in Ludwigshafen, "Yesterday we began operating the large ammonia apparatus with gas circulation . . . for about five hours without interruption. During this whole time it functioned correctly and produced liquid ammonia continuously."[101] Using temper-

Citizens and Transnational Subjects in the Postwar United States and Mexico (Chapel Hill, N.C., 2011). The classic study of the program remains Ernesto Galarza, *Merchants of Labor: The Mexican Bracero Story* (Santa Barbara, Calif., 1964).

[97] Lee G. Williams, as quoted in Linda C. Majka and Theo J. Majka, *Farm Workers, Agribusiness, and the State* (Philadelphia, 1982), 136. The Bracero Program ended in 1964, in part because of broadcast journalist Edward R. Murrow's exposé documentary *Harvest of Shame* (CBS Reports, 1960). On the experiences of Mexican citrus workers in Southern California, see Gilbert G. González, *Labor and Community: Mexican Citrus Worker Villages in a Southern California County, 1900–1950* (Urbana, Ill., 1994). For an analysis of the Southern California citrus industry as a paradigmatic example of managerial corporate capitalism, see H. Vincent Moses, "G. Harold Powell and the Corporate Consolidation of the Modern Citrus Enterprise, 1904–1922," *Business History Review* 69, no. 2 (1995): 119–155.

[98] Harry A. Curtis and Charles M. Pepper, "Our Nitrogen Problem," *Annals of the American Academy of Political and Social Science* 112, no. 1 (1924): 173–183, here 173.

[99] E. L. Baum and S. L. Clement, "The Changing Structure of the Fertilizer Industry in the United States," *Journal of Farm Economics* 40, no. 5 (1958): 1186–1198, here 1189. My estimate of the scope of the global nitrate trade draws upon data from Alejandro Soto Cárdenas, *Influencia Británica en el salitre: Orígen, naturaleza y decadencia* (Santiago, 1998), 75; J. R. Partington and L. H. Parker, *The Nitrogen Industry* (London, 1922), 25; Guillermo Yunge, *Estadística minera de Chile en 1906 i 1907*, 3 vols. (Santiago, 1909), 3: 308–324; and Carmen Cariola Sutter and Osvaldo Sunkel, *La historia ecónomica de Chile, 1830 y 1930: Dos ensayos y una bibliografía* (Madrid, 1982), 126–127. I have also used statistics from Ministerio de Hacienda de Chile, *Memoria de la delegación fiscal de salitreras* (Santiago, 1893, 1897, 1902).

[100] Boyce is best known for founding the Boy Scouts of America on February 8, 1910.

[101] Fritz Haber, as quoted in Vaclav Smil, "Detonator of the Population Explosion," *Nature* 400, no. 6743 (1999): 415.

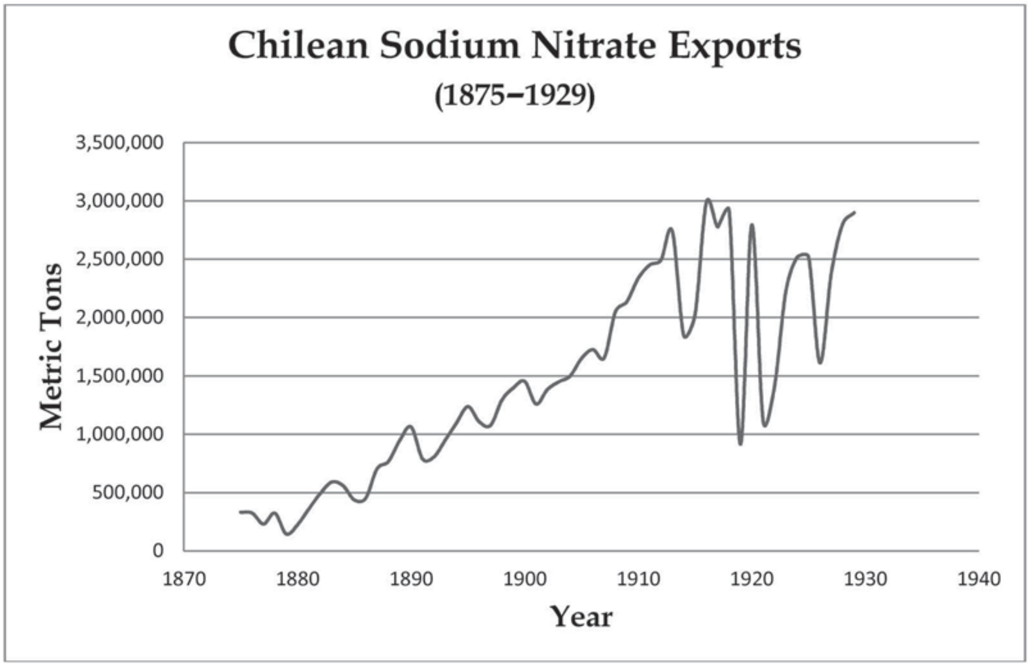

FIGURE 5: Several of the steep declines in nitrate exports from 1919 through the 1920s were due to widespread mining strikes among Chile's increasingly organized coal miners and stevedores. These labor actions disrupted coal-powered coastal rail and steamship transportation and thus dramatically affected the nitrate trade. *Salitre* exports plummeted from 2,919,177 metric tons in 1918 to 803,961 in 1919. See Dirección de Estadística, *Sinopsis Estadística: Año 1920* (Santiago, 1921). Data derived from Carmen Cariol Sutter and Osvaldo Sunkel, *La historia económica de Chile, 1830 y 1930: Dos ensayos y una bibliografía* (Madrid, 1982), 126–127.

atures between 450°C and 600°C, high pressures (200 to 400 atmospheres), and an enriched iron catalyst, Haber produced a reaction of nitrogen and hydrogen that generated ammonia (NH_3). Chemical engineer Carl Bosch standardized the process, allowing BASF to begin commercial ammonia production in 1913. The significance of this development to increased global food production cannot be overstated. As Vaclav Smil wrote in the year 2000, "at least four out of every five children born during the next half a century in Asia, Latin America, and the Middle East will synthesize their body proteins from nitrogen fixed by the Haber-Bosch synthesis of ammonia."[102]

Ironically, this technology that provided the building blocks for life also offered the basis for taking it away. Nitrogen supplies would be a central concern, not only as fertilizer to feed domestic populations, but as a key ingredient of the gunpowder that sustained the fighting in World War I. Manufacturers produced blasting powders with a mixture of saltpeter (either potassium nitrate or sodium nitrate), charcoal, and sulfur. As of 1900, half of the sodium nitrate ($NaNO_3$) imported by the United States went into the manufacture of explosives. A British blockade of the

[102] Quote from Vaclav Smil, *Feeding the World: A Challenge for the Twenty-First Century* (Cambridge, Mass., 2000), 50. Irony abounds in discussions of Haber's legacy. He developed the world's first large-scale chemical weapons during the early years of World War I. See Daniel Charles, *Master Mind: The Rise and Fall of Fritz Haber, the Nobel Laureate Who Launched the Age of Chemical Warfare* (New York, 2005).

Chilean coast looked as though it might shorten the war's duration, but German chemical plants at Oppau and Leuna synthesized enough ammonia to keep their nation's war machine running until its defeat in November 1918. By the mid-1930s, industrial ammonia synthesis had become the dominant source of fixed nitrogen in Europe and the United States.[103]

At the conclusion of World War II, stockpiles of unused nitrogen, awaiting shipment to explosives factories, lay idle. As this nitrogen flooded the market, it caused a drop in fertilizer prices. Farmers in the United States and Europe applied this inexpensive supplement to their crops, causing traditional varieties of wheat and rice to develop taller stems with heavier grains. In wind and rain, these top-heavy plants frequently collapsed. By the 1940s, plant breeder Norman Borlaug and his colleagues were developing semi-dwarf plants with shorter, stronger stalks that could carry the weight of these new nitrogen-rich seed heads. Altering botanical architecture through selective breeding, they produced a "yield blast-off."[104] In 1963, retired USDA scientist Henry M. Beachell discovered a quick-maturing dwarf rice variety, called IR-8, which offered similar benefits to those of Borlaug's semi-dwarf wheat strains. Addressing the 1970 Nobel Peace Prize Committee in Oslo, Norway, Borlaug employed a heady kinetic analogy: "If the high-yielding dwarf wheat and rice varieties are the catalysts that have ignited the Green Revolution, then chemical fertilizer is the fuel that has powered its forward thrust."[105]

As a result of these developments, average global cereal yields tripled during the second half of the twentieth century. In 1950, the world's farmers grew 631 million tons of grain; in 2000, they harvested 1,840 million tons. Despite the fact that the earth's population more than doubled during the second half of the twentieth century, per capita grain production increased 28 percent over this fifty-year period. Many pundits and policymakers refer to this extraordinary upsurge in staple food production as "the miracle of the Green Revolution."[106]

Yet these nitrogen-propelled yield increases came with enormous costs. The implementation of capital-intensive Green Revolution policies encouraged widespread dependence upon chemically intensive monoculture, in which farmers cultivate a single species to the exclusion of all other plants. The limited genetic variability of such drastically simplified systems makes them unusually susceptible to disease. Also, small-scale farmers in Asia, Latin America, and Africa have found it difficult—if not impossible—to afford the fertilizers, pesticides, and irrigation systems needed to cultivate new high-yielding varieties. Spiraling debt burdens from such purchases

[103] For more on the relationship between the development of explosives and the demand for Chilean nitrates, see Stephen R. Brown, *A Most Damnable Invention: Dynamite, Nitrates, and the Making of the Modern World* (New York, 2005), especially chap. 2.

[104] Norman E. Borlaug, as quoted in Nina V. Federoff and Nancy Marie Brown, *Mendel in the Kitchen: A Scientist's View of Genetically Modified Foods* (Washington, D.C., 2004), 64.

[105] Murray H. Milford and E. C. A. Runge, "Beachell and Borlaug: Two Giants of the American Society of Agronomy's First Century," *Agronomy Journal* 99, no. 3 (2007): 595–598. Quote from Norman E. Borlaug, "The Green Revolution: For Bread and Peace," *Bulletin of the Atomic Scientists* 27, no. 6 (1971): 6–48, here 9.

[106] Statistics are from Antony Trewavas, "Malthus Foiled Again and Again," *Nature* 418, no. 6898 (2002): 668–670, here 668; and Mosier, Syers, and Freney, "Nitrogen Fertilizer," 3. On the discourse of Green Revolution "miracles," see Lakshman Yapa, "What Are Improved Seeds? An Epistemology of the Green Revolution," *Economic Geography* 69, no. 3 (1993): 254–273.

have frequently left peasants with no other choice than to sell their farms to wealthy landowners, thereby reviving large-scale plantation agriculture systems typical of the early modern era.[107]

Additionally, reliance on fertilizer-intensive farming has led to eutrophication of aquatic ecosystems. Eutrophication occurs when the runoff of nitrogen and phosphorus from fertilized land stimulates the rapid growth of algae and surface plants, such as water hyacinth. The death and subsequent decomposition of this vegetation consumes dissolved oxygen and causes fish kills. Eventually it creates oxygen-depleted environments, such as the dead zone in the Gulf of Mexico. As these examples suggest, the Green Revolutions of the past two centuries have left a decidedly mixed legacy.[108]

Opportunistic substitutions have long characterized the shifting terrain of modern agriculture. Nitrates displaced guano in the late 1870s, and chemically synthesized ammonia supplanted sodium nitrate in the 1930s. Similarly, transpacific debt peonage offered a viable surrogate for transatlantic chattel slavery during the Age of Abolition, while more recent iterations of industrial food production rely upon vast reserve armies of migrant laborers whose legions exist in the penumbra of national citizenship. Such acts of "creative destruction"—economist Joseph Schumpeter's oft-repeated phrase—continue to test the limits of the biosphere and challenge the margins of human tolerance.[109]

Prior to World War II, South American fertilizer provided an indispensable infusion of nutrients into European and North American soils. This transfer of resources from the Southern to the Northern Hemisphere also laid the groundwork for the input-intensive "second" Green Revolution. For the first time in world history, farmers began relying upon commercially produced fertilizers shipped in bags from distant locations. As Henri Lefebvre claimed in *The Production of Space*, the commodification of natural resources exemplifies one of the central environmental "displacements" of capitalism, namely that "those commodities which were formerly abundant because they occurred 'naturally,' which had no value because they were not products, have now become rare, and so acquired value. They have now to be produced, and consequently they come to have not only a use value but also an exchange value. Such commodities are 'elemental' not least in the sense that they are indeed 'elements.'"[110] This elemental commodification depended upon the ex-

[107] For more on this point, see Cynthia Hewitt de Alcántara, *La modernización de la agricultura mexicana, 1940–1970* (Mexico City, 1979); Eric B. Ross, *The Malthus Factor: Poverty, Politics and Population in Capitalist Development* (New York, 1998); and Vandana Shiva, *The Violence of the Green Revolution: Third World Agriculture, Ecology, and Politics* (Penang, 1991).

[108] Robert W. Howarth and Roxanne Marino, "Nitrogen as the Limiting Nutrient for Eutrophication in Coastal Marine Ecosystems: Evolving Views over Three Decades," *Limnology and Oceanography* 51, no. 1 (2006): 364–376. As some soil scientists have pointed out, soil nutrient depletion is so extreme in many of Africa's agrarian landscapes that there may be no other immediate solution to food production shortages than carefully administered supplements of mineral nitrogen. See, for example, Pedro A. Sánchez, "Tripling Crop Yields in Tropical Africa," *Nature Geoscience* 3, no. 5 (2010): 299–300.

[109] Joseph A. Schumpeter, *Capitalism, Socialism, and Democracy* (New York, 1942), 83.

[110] Henri Lefebvre, *The Production of Space*, trans. Donald Nicholson-Smith (Malden, Mass., 1991), 329. For a detailed account of the commodification of wheat in nineteenth-century Chicago's hinterland, see Cronon, *Nature's Metropolis*, 97–147.

propriated labor of countless debt peons whose mobility was also entwined with new modes of control. Despite the fact that these massive dislocations of nutrients and workers radically altered world history, scholars have overlooked the First Green Revolution.[111]

In part, this omission stems from a persistent failure to recognize the Pacific world as its own "coherent unit of analysis," a starting point for inquiry and a basis for making historical connections.[112] In contrast to Fernand Braudel's Mediterranean, K. N. Chaudhuri's Indian Ocean, and the dynamic field of Atlantic world studies, the Pacific Ocean region—"the enormous water world covering one-third of the Earth's surface, framed by continents, joined by islands"—has had few champions.[113] This dearth of scholarship may derive from the linguistic heterogeneity and cultural diversity of the region, characteristics that pose practical and methodological obstacles. Additionally, Oceania offers no convenient phenotypic analogue to the

[111] Richard Wines dismisses South America's fertilizer trade with the United States, writing only: "A few farmers experimented with Chilean nitrates (also known as caliche or saltpetre), but until changed political conditions and the introduction of the 'Shanks process' in the 1880s, these were too expensive for use in fertilizers"; *Fertilizer in America*, 125. Among historians of California, Chilean nitrates fare even worse. The authors of half a dozen books on California's agricultural history barely mention fertilizer or soil fertility, let alone Chilean nitrates. See Douglas Cazaux Sackman, *Orange Empire: California and the Fruits of Eden* (Berkeley, Calif., 2005); Ian Tyrrell, *True Gardens of the Gods: Californian-Australian Environmental Reform, 1860–1930* (Berkeley, Calif., 1999); David Vaught, *Cultivating California: Growers, Specialty Crops, and Labor, 1875–1920* (Baltimore, 1999); Steven Stoll, *The Fruits of Natural Advantage: Making the Industrial Countryside in California* (Berkeley, Calif., 1998); Donald J. Pisani, *From the Family Farm to Agribusiness: The Irrigation Crusade in California and the West, 1850–1931* (Berkeley, Calif., 1984); and Lawrence J. Jelinek, *Harvest Empire: A History of California Agriculture* (San Francisco, 1982).

[112] This phrase comes from Dennis O. Flynn and Arturo Giráldez, "Introduction," in J. R. McNeill, ed., *Environmental History in the Pacific World* (Burlington, Vt., 2001), ii–xii, here ix. Recent attempts to rectify this omission include Matt K. Matsuda, *Pacific Worlds: A History of Seas, Peoples, and Cultures* (New York, 2012); David A. Chang, "Borderlands in a World at Sea: Concow Indians, Native Hawaiians, and South Chinese in Indigenous, Global, and National Spaces," *Journal of American History* 98, no. 2 (2011): 384–403; David Igler, "On Coral Reefs, Volcanoes, Gods, and Patriotic Geology: Or, James Dwight Dana Assembles the Pacific Basin," *Pacific Historical Review* 79, no. 1 (2010): 23–49; Bruce Cumings, *Dominion from Sea to Sea: Pacific Ascendancy and American Power* (New Haven, Conn., 2009); Ricardo Padrón, "A Sea of Denial: The Early Modern Spanish Invention of the Pacific Rim," *Hispanic Review* 77, no. 1 (2009): 1–27; Amy Ku'uleialoha Stillman, "Pacific-ing Asian Pacific American History," *Journal of Asian American Studies* 7, no. 3 (2004): 241–270; Greg Dening, *Beach Crossings: Voyaging across Times, Cultures and Self* (Philadelphia, 2004); Dennis O. Flynn and Arturo Giráldez, "Cycles of Silver: Global Economic Unity through the Mid-Eighteenth Century," *Journal of World History* 13, no. 2 (2002): 391–427; and Paul W. Blank and Fred Spier, eds., *Defining the Pacific: Opportunities and Constraints* (Burlington, Vt., 2002).

[113] Quote from Matt K. Matsuda, "The Pacific," *American Historical Review* 111, no. 3 (June 2006): 758–780, here 759. Fernand Braudel left an indelible imprint upon Mediterranean scholarship. See Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II*, trans. Siân Reynolds, 2 vols. (New York, 1972–1973). For a selection of the finest writings on the Indian Ocean and the maritime history of India, see Ashin Das Gupta, *The World of the Indian Ocean Merchant, 1500–1800: Collected Essays of Ashin Das Gupta*, comp. Uma Das Gupta (New York, 2001); and K. N. Chaudhuri, *Asia before Europe: Economy and Civilization of the Indian Ocean from the Rise of Islam to 1750* (New York, 1990). For illustrations of the wide-ranging scholarship on the Atlantic world, see Peter Linebaugh and Marcus Rediker, *The Many-Headed Hydra: Sailors, Slaves, Commoners, and the Hidden History of the Revolutionary Atlantic* (Boston, 2000); Joseph Roach, *Cities of the Dead: Circum-Atlantic Performance* (New York, 1996); John Thornton, *Africa and Africans in the Making of the Atlantic World, 1400–1680* (New York, 1992); and Philip D. Curtin, *The Rise and Fall of the Plantation Complex: Essays in Atlantic History* (New York, 1990). American political historians have also built powerful arguments around transatlantic links. See, for example, Daniel T. Rodgers, *Atlantic Crossings: Social Politics in a Progressive Age* (Cambridge, Mass., 1998).

"Black Atlantic." The Pacific has seen many Middle Passages, each with radically different trajectories and destinations.[114]

Even so, the coerced movement of workers offers a structural framework for historical studies of the region. Pairing the nineteenth-century Chinese labor migration to Latin America with the mass relocations of workers from Chile, Bolivia, and Peru to the Norte Grande generates a unique perspective from which to reflect upon the myriad human and ecological reorganizations of the Pacific world over the past two centuries. Further research may reveal that the experiences of Melanesian indentured workers who toiled on Australia's sugar plantations from the 1860s onward, the bonded Japanese laborers who landed on Hawaiian shores during the 1880s, and the Chilean debt peons who served their bosses in the icy streams of Gold Rush California have much in common with those of the Chinese guano diggers and Andean nitrate miners whose labor subsidized the First Green Revolution.[115]

In addition to this scarcity of scholarship on the Pacific world, inattention to the structural changes inaugurated by the guano and nitrate trades results from a relentless portrayal of modern agriculture as a realm of miracles. In the Spring 1992 issue of *Agricultural History*, former secretary of agriculture Orville L. Freeman claimed, "It is not exaggerating to describe U.S. agricultural productivity as the greatest production miracle in the history of mankind."[116] Likewise, Norman Borlaug anticipated "Feeding a World of 10 Billion People: The Miracle Ahead."[117] The scholarly literature is replete with agricultural "miracles" that have allegedly occurred in such disparate places as China, Hungary, Zimbabwe, Vietnam, and Paraguay.[118] Never in history has the extraordinary seemed so resolutely mundane.

[114] Paul Gilroy, *The Black Atlantic: Modernity and Double Consciousness* (Cambridge, Mass., 1993). Erika Lee has highlighted the emergence of "a racial and geographic imaginary in which Orientalism and anti-Asian policies were shared and replicated among white settler societies in the region," which she describes as "the White Pacific"; Lee, "The 'Yellow Peril' and Asian Exclusion in the Americas," *Pacific Historical Review* 76, no. 4 (2007): 537–562, here 550.

[115] The twentieth-century Chinese diaspora has been far more extensively studied than its nineteenth-century counterpart. For examples, see Laurence J. C. Ma and Carolyn Cartier, eds., *The Chinese Diaspora: Space, Place, Mobility, and Identity* (Lanham, Md., 2003); Christopher Fung, "Some Thoughts on the State of Chinese Diaspora Studies," *China Review International* 9, no. 1 (2003): 17–22; and Adam McKeown, *Chinese Migrant Networks and Cultural Change: Peru, Chicago, Hawaii, 1900–1936* (Chicago, 2001). On unfree labor regimes in other parts of the Pacific world, see Bill Willmott, "Chinese Contract Labour in the Pacific Islands during the Nineteenth Century," *Journal of Pacific Studies* 27, no. 2 (2004): 161–176; Ralph Shlomowitz, "Melanesian Labor and the Development of the Queensland Sugar Industry, 1863–1906," in Paul Uselding, ed., *Research in Economic History*, vol. 7 (Greenwich, Conn., 1982), 327–361; David Northrup, *Indentured Labor in the Age of Imperialism, 1834–1922* (New York, 1995), 73; and Edward Dallam Melillo, "Strangers on Familiar Soil: Chile and the Making of California, 1848–1930" (Ph.D. diss., Yale University, 2006).

[116] Orville L. Freeman, "Perspectives and Prospects," *Agricultural History* 66, no. 2 (1992): 3–11, here 8.

[117] Norman Borlaug, "Feeding a World of 10 Billion People: The Miracle Ahead," *In Vitro Cellular & Developmental Biology—Plant* 38, no. 2 (2002): 221–228.

[118] Chris Bramall, "Origins of the Agricultural 'Miracle': Some Evidence from Sichuan," *China Quarterly* 143 (September 1995): 731–755; István Harcsa, Imre Kovách, and Iván Szelényi, "The Hungarian Agricultural 'Miracle' and the Limits of Socialist Reforms," in Iván Szelényi, ed., *Privatizing the Land: Rural Political Economy in Post-Communist Societies* (London, 1998), 21–42; Ken Mufuka, "The Weak Link in Zimbabwe's Agricultural Miracle, 1980–1990: A Case Study of Masvingo Province Resettlement Projects," *Development Southern Africa* 8, no. 3 (1991): 293–304; Thomas Sikor, "Vietnam's Agricultural Miracle: A Preliminary Analysis of Its Causes," *Vietnam's Socio-Economic Development* 6, no. 9 (1996): 40–56; and Richard K. Reed, "Making Paraguay's Agricultural 'Miracle' Work," *Grassroots Development* 9, no. 2 (1985): 17–23.

While it is true that unforeseen advances in agricultural yields have consistently thwarted the apocalyptic prophecies of famine forecasters—from Thomas Malthus (*An Essay on the Principle of Population*, 1798) to Paul R. Ehrlich (*The Population Bomb*, 1968)—the depiction of these exploits as quasi-magical escapes from disaster has also served to conceal the social and environmental contexts in which such paradigm shifts occur. Additionally, it has masked the very real inequalities and material dislocations created by such transitions. Miracles are supernatural events, which cannot be attributed to human agency or the forces of non-human nature. Historians have a significant role to play in demystifying agricultural transitions and the labor regimes that propelled them.[119]

Whether changing the nitrogen cycle with widespread applications of excavated and synthetic fertilizers or amplifying atmospheric carbon concentrations through the combustion of fossil fuels, humans have been altering the earth's elemental flows for many generations. In 2000, as "global warming" headlined discussions of our planetary future, Nobel Prize–winning atmospheric chemist Paul Crutzen coined the term "Anthropocene" to signify the current epoch of geological time, in which *Homo sapiens* has come to exert an unprecedented influence on the cycles of the elements upon which all life depends. The Anthropocene requires a different mode of historicizing. By transcending "the artificial but time-honored distinction between natural and human histories," notes Dipesh Chakrabarty, "climate scientists posit that the human being has become something much larger than the simple biological agent that he or she always has been. Humans now wield a geological force."[120] Evaluating the ways in which humans have acquired geological "agency" will involve a heightened awareness of how we have labored to modify our most literal foundation, the soil. As recently as 2003, J. R. McNeill remarked upon the longstanding scholarly inattention to the history of human interactions with *terra firma*: "It seems curious that the earth itself should not absorb much attention from environmental historians."[121]

A multilayered understanding of these fundamental transformations of the earth as an integrated social and natural system will also require a synthesis of the synoptic overview with the vantage point of matters on the ground. There are no "miracles"

[119] T. R. Malthus, *An Essay on the Principle of Population* (London, 1798); and Paul R. Ehrlich, *The Population Bomb* (New York, 1968). For more detailed discussion of the early warning signs that something was amiss with the Green Revolution's reputedly miraculous transformation of Mexican agriculture, see Angus Wright, "Innocents Abroad: American Agricultural Research in Mexico," in Wes Jackson, Wendell Berry, and Bruce Colman, eds., *Meeting the Expectations of the Land: Essays in Sustainable Agriculture and Stewardship* (San Francisco, 1984), 135–151. For a historical perspective on the failures of Green Revolution "miracle rice" in the Gambia, see Judith A. Carney, "The Bitter Harvest of Gambian Rice Policies," *Globalizations* 5, no. 2 (2008): 129–142. A similar contention, albeit for Java, appears in Richard W. Franke, "Miracle Seeds and Shattered Dreams in Java," in Jeanne Guillemin, ed., *Anthropological Realities: Readings in the Science of Culture* (New Brunswick, N.J., 1981), 357–365.

[120] Paul J. Crutzen and Eugene F. Stoermer, "The 'Anthropocene,' " *IGBP Newsletter* 41 (May 2000): 17–18; Dipesh Chakrabarty, "The Climate of History: Four Theses," *Critical Inquiry* 35, no. 2 (2009): 197–222, here 206. For more on how acknowledgment of the Anthropocene affects the writing of history, see Mike Davis, "Who Will Build the Ark?," *New Left Review* 61 (January–February 2010): 29–46.

[121] J. R. McNeill, "Observations on the Nature and Culture of Environmental History," *History and Theory* 42, no. 4 (2003): 5–43, here 41. McNeill's clarion call echoes the appeal made in Stanley W. Trimble and Pierre Crosson, "Land Use: U.S. Soil Erosion Rates—Myth and Reality," *Science* 289, no. 5477 (2000): 248–250.

in agricultural history, nor are there any easy solutions to the quandaries of global food production in a warmer, more populous world. In the words of Bertolt Brecht,

> . . . it takes a lot of things to change the world:
> Anger and tenacity. Science and imagination,
> The quick initiative, the long reflection,
> The cold patience and the infinite perseverance,
> The understanding of the particular case and the understanding of the ensemble:
> Only the lessons of reality can teach us to transform reality.[122]

[122] Bertolt Brecht, as quoted in Harvey, *Justice, Nature, and the Geography of Difference*, 439.

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