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., (Dordrecht, 2005); Lance H. Gunderson and C. S. Holling, eds., (Washington, D.C., 2002), 37; David Tilman, "The Greening of the Green Revolution," 396, no. 6708 (1998): 211–212; and Gordon Conway, (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 in-

Chilean nitrate firms used a similarly coercive labor regime known as the system. In the 1880s, recruiters for the Nitrate Producers Association began enlisting migrant workers in Chile, Bolivia, and Peru. , 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

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 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 , 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," 57, no. 3 (2005): 677–701, here 698.

[10] Gunther Peck, (Cambridge, 2000), 2.

[11] E. P. Thompson, "Time, Work-Discipline, and Industrial Capitalism," 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., , 2nd ed. (New York, 1994), vol. 1: , 96–122, here 114; and Phyllis Deane, , 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,"

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 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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(Minneapolis, 1996); and David Harvey, (Cambridge, Mass., 1996).

[17] Thomas Bender, ed., (Berkeley, Calif., 2002); and Micol Seigel, "Beyond Compare: Comparative Method after the Transnational Turn," 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," 86, no. 1 (2006): 1–28. Also valuable in this vein are the chapters in Antoinette Burton, ed., (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," 92, vol. 25, no. 3 (2007): 1–7.

[18] Pete Daniel, (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," 109, no. 5 (December 2004): 1405–1438; and Matthew Pratt Guterl, "After Slavery: Asian Labor, the American South, and the Age of Emancipation," 14, no. 2 (2003): 209–241.

[19] Elizabeth Dore, "Debt Peonage in Granada, Nicaragua, 1870–1930: Labor in a Noncapitalist Transition," 83, no. 3 (August 2003): 521–559; Mark Moberg, "Crown Colony as Banana Republic: The United Fruit Company in British Honduras, 1900–1920," 28, no. 2 (1996): 357–381; Alan Knight, "Mexican Peonage: What Was It and Why Was It?," 18, no. 1 (1986): 41–74; David McCreery, "Debt Servitude in Rural Guatemala, 1876–1936," 63, no. 4 (1983): 753–759; and Friedrich Katz, "Labor Conditions on Haciendas in Porfirian Mexico: Some Trends and Tendencies," 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," 14, no. 1 (1986): 50–77; and Brass, "The Latin American System: Some Revisionist Reinterpretations Revisited," 11, no. 1 (1990): 74–103. Calls for a "transnationalizing" of labor history include Michael P. Hanagan, "An Agenda for Transnational Labor History," 49, no. 3 (2004): 455–474; Beverly J.

reminded the readers of the , "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."

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

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 , 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,

[27] Karl Marx frequently used the German term , 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, , 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, (Chicago, 1997), 26–27; John Bellamy Foster, "Marx's Theory of Metabolic Rift: Classical Foundations for Environmental Sociology," 105, no. 2 (1999): 366–405; and Jason W. Moore, "Environmental Crises and the Metabolic Rift in World-Historical Perspective," 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," 33, no. 5 (2007): 794–812, here 799.

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, 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.

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

"Vessels, it appears, are equipped for the business upon the model of slave ships," explained a

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 , "Cases have occurred where men have slipped in at the mouth of the hose as the guano went

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 . . . . 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

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

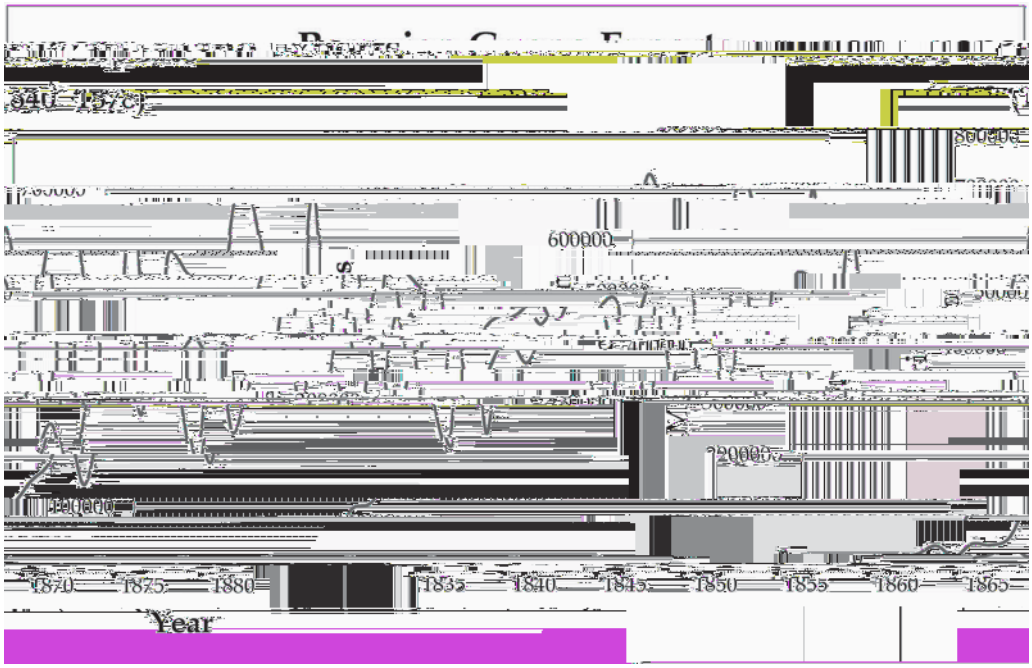

FIGURE 2: : Shane J. Hunt, (Princeton, N.J., 1973), Table 21; José Antonio de Lavalle y García, (Lima, 1914), 41; Antonio Raimondi, "Islas, islotes y rocas del Perú,"

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, , 2nd ed. (Buffalo, N.Y., 1854), 90; William Wallace Fyfe, (London, 1859), 129.

[59] On guano and hop cultivation in Britain, see Celia Cordle, "The Guano Voyages," 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," 23, no. 1 (1970): 112–128.

[60] Wilhelm Ruprecht, "The Historical Development of the Consumption of Sweeteners—A Learning Approach," 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," 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 , the , and the . In 1853, a North Carolina farmer told the 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-

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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," 25, no. 4 (1965): 541–564, here 562; and Bruce F. Johnston, "Agricultural Productivity and Economic Development in Japan," 59, no. 6 (1951): 498–513, here 506. See also Nagahisa Kuroda, "Report on a Trip to Marcus Island with Notes on the Birds," 8, no. 1 (1954): 84–93.

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

[63] Quote from Weymouth T. Jordan, "The Peruvian Guano Gospel in the Old South," 24, no. 4 (1950): 211–221, here 219. For other examples, see A. MacDonald, "Results from Guano Manure," 9, no. 12 (1841): 735–736; and Solon Robinson, "How to Use Guano," 9, no. 5 (1851): 70–71, here 70.

[64] Wines, , 39; Chester McArthur Destler, "David Dickson's 'System of Farming' and the Agricultural Revolution in the Deep South, 1850–1885," 31, no. 3 (1957): 30–39, here 32; Wayne D. Rasmussen, "The Impact of Technological Change on American Agriculture, 1862–1962," 22, no. 4 (1962): 578–591, here 580; and John Solomon Otto, (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, (Baltimore, 1897), 24 n. 1. For accounts of guano use on the Tidewater tobacco

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."

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

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 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 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

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, (Durham, N.C., 2007), 117–157; Eduardo Devés, (Santiago, 1998); and José Bengoa, "Presentación," in Crisóstomo Pizarro, (Santiago, 1986), 5. For a more general summary of workers' movements in the zones, see Julio Pinto Vallejos, (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

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 . [85] Additionally, by the 1920s, Chile was spending more than U.S. $5,000,000 each year on jute sacks

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]

coolie trade and the 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

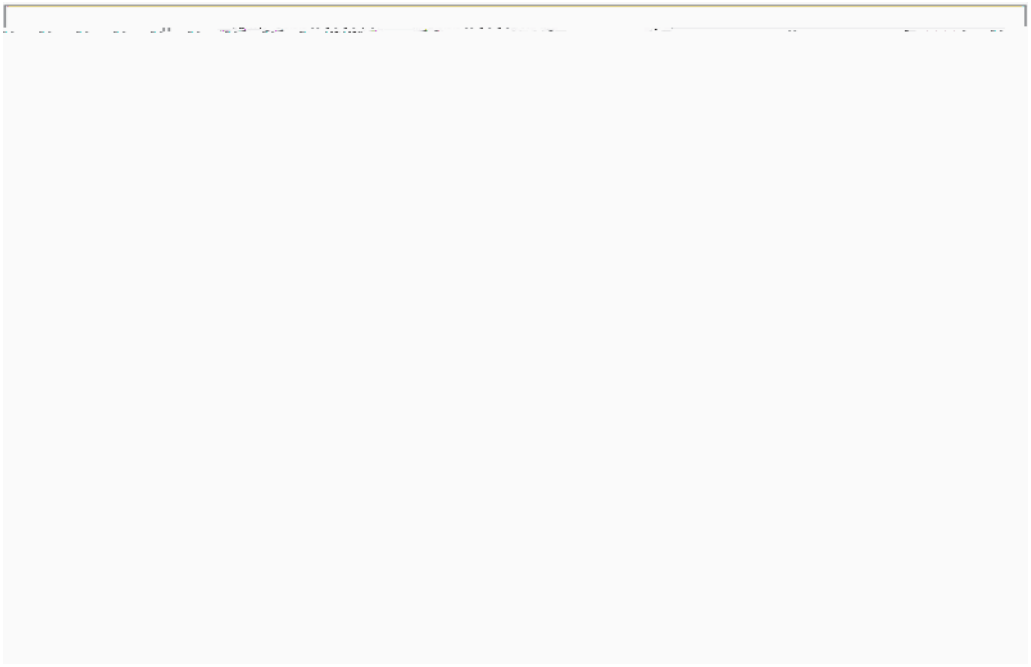

FIGURE 5: Several of the steep declines in nitrate exports from 1919 through the 1920s were due to widespread mining strikes among Chile's increasingly organized coal miners and stevedores. These labor actions disrupted coal-powered coastal rail and steamship transportation and thus dramatically affected the nitrate trade. exports plummeted from 2,919,177 metric tons in 1918 to 803,961 in 1919. See Direccio

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, (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, (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]

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]

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 stud-

While it is true that unforeseen advances in agricultural yields have consistently thwarted the apocalyptic prophecies of famine forecasters—from Thomas Malthus (, 1798) to Paul R. Ehrlich (, 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 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 : "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, (London, 1798); and Paul R. Ehrlich, (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., (San Francisco, 1984), 135–151. For a historical perspective on the failures

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, , 439.

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