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“The greatest victory which the chemist has won in the fight against Nature.” Nitrogenous fertilisers in Great Britain and the British Empire, 1910s-1950s.

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Abstract

This paper analyses the rise of synthetic nitrogen in Great Britain and its Empire, from WWI to the aftermath of WWII. Rather than focus solely on technological innovations and consumption statistics, it seeks to explain how nitrogen was a central element in the expansion of a form of agricultural governance which needed simplified, stable and seemingly universal input/output formulae. In the first half of the twentieth century, nitrogen was thus gradually constructed as a global indicator of development, as it was particularly adapted to scientific and political regimes increasingly relying upon abstraction and quantification. Yet, the history of nitrogenous fertilisers in the interwar years also shows that this can not be reduced to a simple story of triumphant modernity, as their development and globalisation was imperfect, unstable, accompanied by resistance and the resilience or emergence of other models. Rather than assuming an all-powerful “state” project, the paper thus seeks to recover the multiplicity of actors, and attempts to account for the rise of nitrogenous fertilisers, not just as the progressive application of a technological breakthrough, but as a difficult process embedded in technological, financial and military constraints, corporate strategies, political imperatives and the changing institutional framework of agricultural research.

Keywords

Fertilizers, nitrogen, agriculture, expertise

In 1949, upon the invitation of his brother Julian, Aldous Huxley published a paper in the UNESCO “Food and People” Series, *The Double Crisis*, in which he predicted an impending demographic and ecological disaster. With increasing population and decreasing soil fertility due to erosion, the world was

now faced, according to Huxley, with a true Malthusian crisis.¹ UNESCO then invited Sir E. John Russell, agricultural scientist and President of the British Association for the Advancement of Science, to mount a reply to Huxley's ideas.² According to Russell, the present crisis would be avoided, as previous Malthusian forecasts had been, thanks to science and technology which always pushed back any "limits to resources." According to Russell, one of the most efficient tools against global hunger were nitrogenous fertilizers, the use of which could and should be encouraged as quickly as possible.³ In the 1950s, Russell's message was taken up by the Rockefeller Foundation and international organisations which, in combination with the new technologies that enabled to create new breeds of rice and wheat that were highly responsive to nitrogen, kickstarted the "Green Revolution" marked notably by a dramatic increase in the production and consumption of nitrogenous fertilisers.⁴

The history of the nitrogen cycle has recently come under increasing scrutiny by historians, who have sought to explain the fundamental contribution of this element to the history of the twentieth century.⁵ Most of these studies have focused on the two key defining moments in this story, first the birth of a global trade in "artificial" fertilisers coming from South America in the 1840s (Peruvian guano, then Chilean nitrates), then with the discovery of the Haber-Bosch process (1913), which enabled nitrogen from the atmosphere to be synthesised in the form of ammonia.⁶ Although much more is now known about the dual origins of this globalisation of nitrogen, narratives centered on technological innovation seem to assume a continuous and gradual process of development and globalisation following the birth of a new technology which naturally replaced former practices of soil management. Yet, the history of the development of nitrogenous fertilisers shows that this can not be reduced to a simple story of triumphant modernity, and that it is necessary to analyse more precisely the historical set of factors and conditions which allowed its gradual domination.⁷ As recent trends in the history of science and technology have emphasised, "the subjection of nature to number, weight and measure," of which the development of nitrogenous fertilizers was a very important aspect, was indeed imperfect, unstable, accompanied by negotiation, transformation, resistance and the resilience or emergence of other models.⁸ This essay will strive to show that it was not until the end of WWII that the

¹ R. S. Deese, "The New Ecology of Power: Julian Huxley and Aldous Huxley in the Cold War Era," J. R. McNeill and Corinna Unger, eds., *Environmental Histories of the Cold War* (Cambridge: Cambridge University Press, 2010), 292-94. Alison Bashford, *Global Population: History, Geopolitics and Life on Earth* (New York: Columbia University Press, 2014): 278-79.

² Aldous Huxley and E. John Russell, *La Double Crise; Pour sortir de l'Impasse* (Paris: Dunod, 1950).

³ E. J. Russell, *World Population and World Food Supplies* (London: Allen & Unwin, 1954): 65.

⁴ Alison Bashford, *Global Population*, p. 274-275 (see note 1); Nick Cullather, *The Hungry World: America's Cold War Battle against Poverty in Asia* (MA: Harvard University Press, 2010): 187-204.

⁵ Brett Clark and John Bellamy Foster, "Ecological Imperialism and the Global Metabolic Rift: Unequal Exchange and the Guano/Nitrates Trade," *International Journal of Comparative Sociology* 50 (2009): 311-334; Edward D. Melillo, "The First Green Revolution: Debt Peonage and the Making of the Nitrogen Fertilizer Trade, 1840-1930," *American Historical Review* 117 (2012): 1028-1060; Gregory T. Cushman, *Guano and the Opening of the Pacific World: a Global Ecological History* (Cambridge: Cambridge University Press, 2013).

⁶ Vaclav Smil, *Enriching the Earth: Fritz Haber, Carl Bosch and the Transformation of World Food Production* (Cambridge: The MIT Press, 2004); G. J. Leigh, *The World's Greatest Fix: A History of Nitrogen and Agriculture* (Oxford: Oxford University Press, 2004); Thomas Hager, *The Alchemy of Air* (New York: Random House, 2008).

⁷ Christophe Bonneuil and Jean-Baptiste Fressoz, *L'événement Anthropocène: la Terre, l'Histoire et Nous* (Paris: Seuil, 2013): 125-129; Hugh S. Gorman, *The Story of N: A Social History of the Nitrogen Cycle and the Challenge of Sustainability* (New-Brunswick: Rutgers University Press, 2013).

⁸ Simon Schaffer, "Introduction to Part II," Lissa Roberts et. al., eds., *The Mindful Hand: Inquiry and Invention from*

substitution of organic manure by synthetic nitrogen was envisaged as a global solution to agricultural problems. Before that, the globalisation of this product was faced with numerous difficulties, hesitations and misgivings, and the role of the two World Wars was fundamental, not only in developing productive capacity, but also in furthering the integration of fertilizer research and the chemical industry in political organisations, and in favoring the emergence of new forms of planning in which the focus of expertise had to be narrowed down to one or two chemical elements. This paper therefore attempts to account for the globalisation of nitrogen in the first half of the twentieth century not as the story of a technological breakthrough and the progressive application and transfer of more efficient knowledge and inputs, but as a difficult process embedded in a whole set of technological, financial and military constraints, corporate strategies, and political imperatives.

If Great Britain had undoubtedly been at the forefront of the transition to a new model of agriculture characterised by the use of nitrogenous fertilisers in the 1840s, Peruvian guano and Chilean nitrates were not necessarily perceived as miracle products.⁹ It is thus quite clear that by the 1870s, the initial wave of optimism for “artificial” fertilisers had declined, among agricultural researchers as well as farmers. Fertilisers indeed featured much less prominently in specialist journals at the end of the nineteenth century than had been the case in the mid-Victorian era, while many farmers found that there was no correspondence between the rise in expenditure on input and the rise in profit.¹⁰ If Great Britain consumed about 50% of the total global market of nitrogen in the 1850s and 1860s, this proportion declined very rapidly to no more than 5 % in the 1910s.¹¹ In addition to the question of cost, it was discovered that guano and nitrates had to be used with caution, as they were said to encourage straw growth, mildew and to have possible acidifying effects on soils.¹² The leading text on soil science in the early twentieth century thus insisted on the deterioration of soil texture that had been caused by the use of nitrate of soda and other fertilisers, and lay a much greater emphasis on the role of humus and farmyard manure.¹³

Thanks to its gas industry, Great Britain had also been at the forefront of the actual beginnings of the “production” of nitrogen. In 1863, the Alkali Act had rendered the removal of ammonia from illuminating gas compulsory, and the gas industry had therefore begun to produce sulphate of ammonia, another nitrogenous fertiliser, more widely in order to cover the cost of washing and filtering.¹⁴ British production

Late Renaissance to Early Industrialization (Royal Netherlands Academy of Arts and Sciences, 2007), 90; Kapil Raj, “Beyond Postcolonialism ...and Postpositivism: Circulation and the Global History of Science,” *Isis* 104 (2013): 337-347.

⁹ W. M. Mathew, “Peru and the British Guano Market, 1840-1870,” *The Economic History Review* 23 (1970): 112-128; W. M. Mathew, *The House of Gibbs and the Peruvian Guano Monopoly* (London: Royal Historical Society, 1981).

¹⁰ N. Goddard, “Information and Innovation in early Victorian farming systems,” B. A. Holderness and M. Turner, eds., *Land, Labour and Agriculture, 1700-1920* (London: Bloomsbury Academics: 1991), 171.

¹¹ J. L. Van Zanden, “The First Green Revolution: the Growth of Production and Productivity in European Agriculture, 1870-1914,” *The Economic History Review* 44 (1991): 224.

¹² E. J. T. Collins, *The Agrarian History of England and Wales, 1850-1914* (Cambridge: Cambridge University Press, 2000): 125. See also W. G. T. Packard, “The History of the Fertiliser Industry in Britain,” *Proceedings of the Fertiliser Society* 19 (1952): 5-42.

¹³ A. D. Hall, *The Soil: An Introduction to the Scientific Study of the Growth of Crops* (New York: E. P. Dutton, 1908): 43-47 & 252.

¹⁴ Collins, *The Agrarian History of England and Wales, 1850-1914*, p. 1034-35 (see note 12).

had expanded very quickly, from 45,000 tons of sulphate of ammonia a year in 1875 to 200,000 tons a year in 1900 which represented 40 % of total world production. Yet British farmers did not seem to trust this fertiliser and nearly all the sulphate of ammonia was exported to Germany.¹⁵ More generally, Great Britain relied much more upon the continuing import of food than upon the development of the production and consumption of nitrogen, which did not yet have the strategic importance it later acquired. An important exception was the President of the British Association for the Advancement of Science, William Crookes, for whom nitrogen was the key to the survival of the “great Caucasian race.” Crookes argued in 1898 that “civilised nations,” who relied on wheat for their staple food, were threatened with starvation by rising population and shrinking arable land. In the fight between the West and the rest of the world, the only salvation for the “bread-eaters of the world” lay in devising a way to fix the nitrogen in the atmosphere.¹⁶

If Crookes pinned all his hopes on the chemist, his message does not seem to have carried much weight in 1900s Great Britain, where the policy of importing grain was, if anything, reinforced.¹⁷ Three new technologies to fix nitrogen began to be developed in the late 1900s, the arc process, the calcium cyanamide process and the Haber-Bosch process, developed in Germany from 1909, but there was no real attempt to develop this new branch of the chemical industry in Great Britain, despite the strategic nature of nitrogen compounds, necessary for the manufacture of both fertilizers and explosives.¹⁸ As opposed to Germany, which rapidly developed its production of synthetic nitrogen during WWI, there was no real increase in the production of by-product ammonia in Great Britain, which remained entirely dependent upon Chilean nitrates in order to manufacture its munitions. This dependence obviously raised concerns and in June 1916, a Nitrogen products Committee was appointed by Lloyd George, then Minister of Munitions, to report on the post-war position of Britain regarding nitrogenous products. The report of the Committee was published in May 1919 and recommended setting up a plant to synthesise nitrogen from the atmosphere, using the Haber-Bosch process or a related one.¹⁹ It was thus only by the end of WWI that nitrogen had become a truly strategic element, upon which “the security of a nation” depended, and for which the State needed therefore to provide the very important initial capital outlay.²⁰ The Report of the Nitrogen Products Committee also emphasised the role that the Empire would have to play in the new quest for nitrogen independence, as the creation of a “large export trade,” particularly in the Empire, was the condition for the vastly increased productive capacity envisaged (for war time needs) to be economic in peace time.²¹ However, in spite of this ambition to create a large global market for synthetic nitrogen, the fixation of nitrogen was primarily a

¹⁵ Ministry of Munitions of War, *Final Report of the Nitrogen Products Committee* (London: HMSO, 1919): 12.

¹⁶ William Crookes, *The Wheat Problem, based on Remarks made in the Presidential Address to the British Association at Bristol in 1898* (London: John Murray, 1900): 7, 37.

¹⁷ Avner Offer, *The First World War: An Agrarian Interpretation* (Oxford: Clarendon Press, 1989): 225.

¹⁸ Roy M. MacLeod, “Chemistry for King and Kaiser: Revisiting Chemical Enterprise and the European War,” A. S. Travis et. al., eds., *Determinants in the Evolution of the European Chemical Industry, 1900-1939* (Dordrecht: Kluwer Academic Publishers, 1998), 32.

¹⁹ L. F. Haber, *The Chemical Industry, 1900-1930: International Growth and Technological Change* (Oxford: Clarendon Press, 1971): 85-97; Smil, *Enriching the Earth*, p. 102 (see note 6); Werner Abelshauser et. al., *German Industry and Global Enterprise. BASF: The History of a Company* (Cambridge: Cambridge University Press, 2003): 151-175.

²⁰ Ministry of Munitions, *Final Report of the Nitrogen Products Committee*, p. 5 & 85 (see note 15).

²¹ Ministry of Munitions of War, *Summary of Final Report of the Nitrogen Products Committee*, June 1919, National Archives, Kew (thereafter NA), CAB/24/81, 119.

“technology of autarky” and the immediate goal assigned to this new branch of the chemical industry was to substitute synthetic for imported nitrogen.²² If guano and nitrates had always been labeled “artificial” manures, they were not only located far away and their importation thus susceptible to disruption, but, more importantly, they remained “natural” and finite resources as the nearly exhausted supplies of guano made very clear.

The production of synthetic nitrogenous fertilisers was clearly conceived as a way to make Great Britain less dependent on global trade, not only of nitrogen, but more generally of foodstuffs. The war indeed also prompted the wish to increase “Home-Grown Food Supplies (...) in the interests of national security,” which led the Ministry of Reconstruction to emphasise the necessity to increase fertiliser consumption, and to single out nitrogen as the key strategic element : “All sources of nitrogen supply must be tapped to the fullest extent, and we hope that the resources at our command in the matter of nitrogenous fertilisers may be so developed as to render this country, in the event of a future war, independent of foreign supplies.”²³ The leading centre of fertiliser research in Great Britain, the Rothamsted experimental station, also started to become much more influential in the formulation of agricultural policy, and the leading voices on agricultural science became with the War much less equivocal about the use of artificial fertilisers.²⁴ WWI thus gave increased resonance to Crooke's address, which was reedited in 1917 with a new introduction by Lord Rhondda, Minister of Food Control, who criticised the conservatism of British farmers and took Germany and its fixation of nitrogen as an example : “If we are to feed ourselves, we must begin by securing a continual provision of the fixed nitrogen which is necessary to feed our best food, and which we can begin to make for ourselves, in any quantities, whenever we please.” As agricultural scientist and future president of the Royal Statistical Society Henry Rew put it in a postscript to the 1917 edition, it seemed that the chemist had finally “come to the rescue.”²⁵

The British Government therefore started preparations for setting up a nitrogen fixation plant at Billingham but enthusiasm for this enterprise soon receded, due to the technical difficulties encountered, the amount of capital involved, as well as to pressure from the Treasury to see government activities wound down. Even within the Ministry of Munitions, some voices called for a complete halt to the project. However, Lord Moulton, Director of the Department of Explosives Supply, managed to keep the project alive by finding a private partner to take over the project. In December 1919, a formal announcement was made in the press that the Billingham factory was to be disposed of under “certain conditions,” but the deal had actually been concluded before²⁶. Two months before the announcement, the Minister of Munitions informed the War Cabinet that Brunner & Mond had already an offer, which was, in his opinion, “too small”

²² David Edgerton, *The Shock Of The Old: Technology and Global History since 1900* (London: Profile Books, 2008): 116.

²³ Ministry of Reconstruction, *Summaries of Evidence taken before the Agricultural Policy Sub-Committee of the Reconstruction Committee* (London: HMSO, 1918): 125.

²⁴ John E. Russell, *Plant Nutrition and Crop Production* (Berkeley: University of California Press, 1926): 24; A. D. Hall, *Agriculture after the War* (New York: E. P. Dutton and Co., 1916): 100.

²⁵ William Crookes, *The Wheat Problem*, 3rd edition with an introduction by Lord Rhondda (London: Longmans, 1917): 31, 36-37, 102 & 103.

²⁶ “Nitrate Factory, Billingham,” *The Times*, 3 December, 1919, p. 10.

but he thought “it unlikely that a better offer would be forthcoming.”²⁷ There was indeed, probably no other British chemical company familiar enough with the high-pressure processes involved and powerful enough to develop with this new capital-intensive technology. From the beginning of the negotiations, Brunner & Mond clearly benefited from the absence of any competition and held the stronger hand. Contrary to the very optimistic outlook on post-war consumption laid out in the *Report* of the Nitrogen Products Committee, Brunner & Mond were fully aware of the possibility of over-production. They emphasised the financial and technical difficulties involved in the project and made it very clear that they would not consider taking over the works without considerable government assistance. The government was thus forced to let go of this works, with about only half of the initial funds spent refunded to them by Brunner & Mond, in exchange of which the chemical company agreed to produce “a minimum output of 20 tons of ammonia per day” which could be used to manufacture explosives in case of war.²⁸

Thus, without the War and the intervention of the State, the creation of a synthetic factory might not have been possible since the initial outlay of capital was very important and the strategic importance of a domestic source of nitrogen had become much more obvious. Without the War too, it is highly unlikely that Brunner & Mond would have had the resources to invest in such a venture, as the capital of the company had doubled between 1913 and 1919. Also, even though the terms of the Treaty of Versailles did not explicitly compel BASF to hand all its technology to the victors, Brunner & Mond claimed that the Treaty entitled them to use patents and documents bought, with dubious legality, in December 1920 from two Alsatian engineers who had worked at BASF factories during the war. Finally, the war brought about a much closer collaboration between the State and the chemical industry, which would continue in the 1920s and 1930s, as representatives from the Ministry of Munitions were invited to sit on the board of the ammonia branch of Brunner & Mond.²⁹

The War had not solved all problems, however. The fixation of atmospheric nitrogen was very capital-intensive, and this forced Brunner & Mond to accept a merger with the Nobel Company to form Imperial Chemical Industries in the late 1920s.³⁰ More importantly, the enthusiasm for nitrogen fixation spurred on by the war had obviously not been limited to Great Britain, and various schemes were set up so that by 1929 the entire global production of nitrogen (including Chilean nitrates) was three times as important as in 1913.³¹ However, this development and rapid globalisation of nitrogenous fertilisers was faced with considerable difficulties. Thus, when the main actors of the nitrogen industry met in 1928, F. C. O. Speyer, who represented the British sulphate of ammonia industry, professed “an era of nitrogen plenty”. Even before the

²⁷ Memorandum by the Minister of Munitions, “Disposal of H. M. Nitrogen Factory, Billingham on Tees, 27 October 1919,” NA, CAB 24/92/2.

²⁸ The arrangement was made as discreetly as possible and it was not until five years later that criticisms were expressed in the House of Commons regarding the preferential conditions granted to Brunner & Mond. House of Commons Debate, “Nitrogen Fixation,” *Hansard*, 07 April 1925, vol. 182, cc 2019-21.

²⁹ W. J. Reader, *Imperial Chemical Industries: A History. Vol. I. The Forerunners, 1870-1926* (London: Oxford University Press, 1970): 358-364

³⁰ W. J. Reader, *Imperial Chemical Industries: A History. Vol. II: The First Quarter-Century, 1926-1952* (London: Oxford University Press, 1975): 4-12.

³¹ Mirko Lammer, *The World Fertilizer Economy* (Stanford: Stanford University Press, 1957): 101-102. On the projects in the United-States, see Gorman, *The Story of N*, p. 86-90 (see note 7).

Depression, Speyer's diagnosis was gloomy : “will it be possible for the world to consume, year by year, the great increase in the production of nitrogen which will take place within the next three years if the larger part of all the programmes of construction announced in various countries is carried out?” For the three years coming, Speyer forecast a 50 % increase in the production of synthetic nitrogen, while the production of by-product sulphate of ammonia would also keep expanding. This would mean that more than 2.3 million tons of nitrogen would be produced by 1931 while consumption in 1928 stood at less than 1.5 millions tons. The nitrogen industry, as Speyer explained, therefore ran the risk of seeing its prices and profits fall steeply. Interestingly, overpopulation and famine did not figure prominently in the discourse of the nitrogen industry in the late 1920s, quite the contrary : according to Speyer, there would be 68.7 million additional human beings on the planet in 1931, who would only absorb around two thirds of the additional calories produced by the increased supply of nitrogen, resulting in “serious economic disturbance.”³² Although Speyer's calculations may have been crude, and did not include non-calorific crops such as tea, cotton or tobacco, which represented an important part of the use of nitrogenous fertilisers outside Europe, his contribution shows the acute fears of overproduction and price drops voiced by the fertiliser industry even before the onset of the Great Depression, and the attendant need to develop new markets.

The immediate concern of the nitrogen industry was, however, to avoid overproduction and the late 1920s and early 1930s saw a series of agreements leading to the creation of cartels and the restriction of production. A controlling agency, the International Nitrogen Association, was thus set up in 1930 in London. After a brief interval between July 1931 and July 1932, during which the INA was dissolved and a price war occurred, the INA was set up again and controlled the nitrogen trade throughout the 1930s. One of the ways through which the INA maintained prices for nitrogen was by paying compensation for new plant projects to be halted or delayed, in a very similar fashion to what has recently been described as the “system of sabotage” organised by the oil companies in the interwar period.³³ The INA also issued export allocations, allowing each producer a share of world trade. These agreements were quite successful, as they allowed sales to surpass production from 1931 onwards, while stocks had been piling up since 1926.³⁴ Disaster had been avoided and prices were maintained but this had been only achieved through a strong curtailment of productive capacity, as the total production of sulphate of ammonia in Great Britain was halved.³⁵ Despite the committed effort by Imperial Chemical Industries to present “the manufacture of nitrogen fertilisers from “that inexhaustible source, the atmosphere” as “the greatest victory which the chemist has won in the fight which civilisation is making against the forces of Nature,” it was clear that the assessments made by the Nitrogen products Committee and even by Brunner & Mond in the early 1920s had been too optimistic.³⁶

³² F. C. O. Speyer, *Some Nitrogen Problems* (London: Vaccher and sons, 1928): 2-7.

³³ Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (London: Verso, 2013 (1st ed. 2011)): 40-41.

³⁴ Lammer, *The World Fertilizer Economy*, p. 171-174 (see note 31); Reader, *Imperial Chemical Industries: A History. Vol. II*, p. 158 (see note 30).

³⁵ Principal Supply Officers Committee, Board of Trade, “Memorandum on Nitrogen products,” 1936, NA, SUPP 3/85. Economic Committee Sub-Committee on Fertilisers, “Draft Survey of the Commercial fertiliser Industry,” 9 June 1950, NA, BT 64/1274, p. 137-138.

³⁶ W. V. Blewett, “The Chemist and Agriculture,” *The Australian Quarterly* 1 (1929): 102.

As the consumption of sulphate of ammonia among British farmers remained rather low, the leaders of ICI were acutely aware of the need for increased research and propaganda to boost consumption and of the necessity to target imperial and foreign markets. They secured the appointment of Frederick Keeble (former Professor of Botany at Oxford) to their department of Research and Propaganda, and set up an agricultural research station at Jealott's Hill which opened in 1929. Meanwhile, Nitram Ltd., which acted as the selling department of the British Sulphate of Ammonia Federation and of Imperial Chemical Industries, also offered financial support to research stations and agricultural colleges in Great Britain, Palestine, Egypt, Canada, Nyasaland, South Africa and the Malay States.³⁷ The perspectives of increasing consumption in the Empire remained, however, rather disappointing in the 1930s, and artificial manures were confined to the main cash crops such as rubber in Malaya, tea in Ceylon and sugar in the West Indies. Far from being marked by the unequivocal promotion of fertilisers, the interwar period was characterised, especially in Africa, by the reevaluation of local agricultural practices, and by a “new ecological approach,” marked by surveys emphasising local particularities and the interdependence, within particular ecosystems, of a multiplicity of phenomena and variables³⁸. Nitrogen had thus not yet been singled out as the key, standardised prophylaxis against global agricultural issues. In the late 1930s, there were rising concerns about erosion and the need to preserve the fertility of tropical soils, and there was very little mention of synthetic fertilisers in this regard, as the focus lay on the preservation of organic matter, through soil cover and the development of composting.³⁹ In the late 1930s, the Agricultural Advisor to the Secretary of State for the Colonies, Frank Stockdale, even argued that “the great importance which was formerly attached to nitrogen has been found to have been mistaken.”⁴⁰

If WWI had kickstarted a very rapid development of nitrogen fixation, finding outlets for this increased production remained very problematic. As far as exterior markets were concerned, China at first seemed to be the most promising one for ICI. The company set up an elaborate organisation to encourage research and advertising there but its operations regarding nitrogenous fertilisers in China were all but abandoned by the mid 1930s. There was indeed considerable resistance to this new technology, some peasants realising that nitrogenous fertilisers were not necessarily profitable in the case of rice cultivation, and could even have deleterious effects on their soils. Apart from the general unwillingness of Chinese peasants to abandon their practices of using night-soil, composting and soybean cakes to fertilize their land, ICI was faced by a campaign against its fertilizers by some local authorities who chose to tax their imports heavily, sometimes even banning them.⁴¹

³⁷ Royal Commission on Agriculture in India, *Vol. X : Evidence taken in England* (Calcutta: Government of India Central Publication Branch, 1927): 473-474.

³⁸ Joseph Morgan Hodge, *Triumph of the Expert: Agrarian Doctrines of Development and the Legacies of British Colonialism* (Athens: Ohio University Press, 2007): 153; Helen Tilley, *Africa as a Living Laboratory* (Chicago: The University of Chicago Press, 2011): 115-168.

³⁹ R. M. Gorrie, “The Problem of Soil Erosion in the British Empire with Special Reference to India,” *Journal of the Royal Society of Arts* 86 (1938): 901-92; Daniel Hall, *The Improvement of Native Agriculture in Relation to Population and Public Health* (London: Oxford University Press, 1936).

⁴⁰ Frank Stockdale, *Report on a Visit to Malaya, Java, Sumatra and Ceylon* (London: Colonial Advisory Council of Agriculture and Animal Health, 1939): 19.

⁴¹ Patrick Brodie, *Crescent over Cathay: China and ICI, 1898 to 1956* (Hong Kong: Oxford University Press, 1990): 96-140.

ICI also spared no effort to develop a new market for their products in India, where they spent 25 % of their entire research and propaganda budget.⁴² In the words of another speaker present at the 1928 Nitrogen Conference, “the fertiliser propagandist considering India as a field of operations is faced with a proposition more formidable than the propounding of a scheme for the whole of Europe.”⁴³ ICI notably used local development associations and agricultural departments to sell their ammonium sulphate. In the Bombay province, for example, ICI sold their ammonium sulphate through local development associations. In Bihar, the agricultural department conducted more than 6000 demonstrations to show the cultivators the advantage of fertilisers, mostly relying on free distribution. In Sind, arrangements were made between ICI, the experimental station and local shopkeepers to make fertilizers more easily available to peasants and, “as a result of successful demonstrations” the larger landowners were made to realize “the value of using sulphate of ammonia in preference to farmyard manure.”⁴⁴ It may thus be said that the “globalisation” of nitrogen did not proceed at first from a state or imperial initiative but from a nascent form of cooperation at the local level between a transnational company and local organisations.

All in all, however, the prospects for India to become a flourishing market remained rather disappointing. The representatives of the fertiliser companies usually complained of the distinctly unhelpful attitude of colonial officials and scientists.⁴⁵ At the end of the nineteenth century, the consulting chemist J. A. Voelcker had pointed to the lack of nitrogen in Indian soils, but had blamed this on the vast exports of crops and manure (oilseeds) which removed “a considerable amount of the soil constituents,” as well as the lack of firewood which forced Indian peasants to burn their cattle-dung rather than use it as manure.⁴⁶ Later on, as artificial fertilisers became more available, it was not felt that those were a suitable solution to Indian agricultural issues.⁴⁷

Representatives of the fertiliser industry such as Speyer argued that the rise in fertiliser consumption depended “upon the provision of reliable information as to the economic use of fertilisers by the cultivator,” and this information, it was felt, could “only be supplied by the Department of Agriculture”, so that the expansion of the fertiliser trade in India depended upon the “co-operation between the officers of this department and the fertiliser industry.”⁴⁸ Yet when, upon the occasion of the 1927 Royal Commission, the British Sulphate of Ammonia Federation proposed the creation of a central organisation for research on fertilisers as a way to promote this collaboration, the offer was swiftly turned down. Some of the leading scientists in India, such as Albert Howard and Gilbert Fowler, even expressed their fierce opposition to the

⁴² Royal Commission on Agriculture in India, *Vol. X: Evidence taken in England*, p. 473-474 (see note 37).

⁴³ T. H. J. Carroll, *Fertilizer Problems and Prospects in India* (London: Vaccher & sons, ltd., 1928): 1.

⁴⁴ Imperial Council of Agricultural Research, *Agriculture and Animal Husbandry in India, 1937-38* (Calcutta: Government of India Press, 1940): 111.

⁴⁵ Royal Commission on Agriculture in India, *Vol IV: Evidence Taken in the Bengal Presidency* (Calcutta: Government of India Central Publication Branch, 1927): 296.

⁴⁶ J. A. Voelcker, *Report on the Improvement of Indian Agriculture* (Calcutta: Government of India Press, 1893): viii-xi.

⁴⁷ Royal Commission on Agriculture in India, *Report of the Royal Commission on Agriculture in India* (Calcutta: Government of India Central Publication Branch, 1927): 89-91.

⁴⁸ *Ibid.*, p. 499. Royal Commission on Agriculture in India, *Abridged Report* (Calcutta: Government of India Central Publication Branch, 1927): 300.

development of synthetic nitrogenous fertilisers, arguing instead in favour of the conservation and recycling of waste material.⁴⁹ In the late 1930s, important research was indeed conducted in the provinces in order to improve soil fertility through organic fertilisers like compost or green manures. Fertilisers were actually only one among the many questions treated by the new discipline of soil science (an Indian Society of Soil Science was founded in 1934), which lay particular emphasis on non-chemical questions, such as the importance of organic matter and on “the physical relationship of the soil in elucidating the problems relating to erosion, drainage, irrigation and soil alkalinity.”⁵⁰ Between the wars, imperial administrators and soil scientists did not really promote synthetic fertilisers uncritically, and if this period may have been characterised by the “triumph of the expert”, expertise remained multifaceted. In other words, there was no single state or imperial force pushing towards a blind “chemicalisation” of agriculture.

It was only with WWII that synthetic nitrogen was to become an integral part of a wide-ranging, comprehensive military, industrial and agricultural policy, and that Rothamsted and ICI were to make their expertise indispensable to the State. From 1936, preparations for war in Great Britain meant that productive capacity was to be greatly expanded. The Board of Trade did not think that new plants were needed but restrictions to ban the export of sulphate of ammonia started to be issued.⁵¹ The War Office, on the other hand, felt that it was necessary to erect new plants, as the concentration of nitrogen fixation at Billingham rendered the manufacture of explosives extremely vulnerable, in case of an air attack. By 1936, the War Office therefore entered negotiations with ICI to set up a nitrogen fixation plant in Scotland. ICI insisted that this new plant would not be used in peace time and, thus, that all the costs would have to be borne by the Government. There were some disagreements in the course of the construction of the Mossend Factory, as it was felt by the Treasury that more time should have been taken to negotiate with ICI for a fairer price and that the estimates for nitrogen requirements had been calculated without enough care, while the War Office insisted that construction ought to begin “at the earliest possible moment.”⁵² Once again, ICI clearly held the upper hand in those negotiations as they were the only company in Great Britain to master the technology, and the War Office felt pressed by the fact that it would take two years to set up this factory.

In the end, 4 government plants, managed by ICI, were erected between 1936 and 1943, at Mossend (1939), Dowlais (1940), Heysham (1942) and Prudhoe (1943), which almost doubled the prewar capacity. This wartime development of productive capacity was responsible for the fact that in 10 years, from 1938 to 1948, not only did world production remain stable despite the destruction of an important part of the German productive capacity, but the Commonwealth share in this production nearly trebled, from 7% of world

⁴⁹ Albert Howard & Y. D. Wad, *The Waste Products of Agriculture - Their Utilization as Humus* (London: Oxford University Press, 1931); Gilbert J. Fowler, *An Introduction to the Biochemistry of Nitrogen Conservation* (London: Edward Arnold, 1934).

⁵⁰ Madhumita Saha, “Food For Soil, For People: Research on Food Crops, Fertilizers, and the Making of 'Modern' Indian Agriculture,” *Technology and Culture* 54 (2013): 289-316. Imperial Council of Agricultural Research, *Agriculture and Animal Husbandry in India*, p. 105 (see note 44).

⁵¹ Principal Supply Officers Committee, Board of Trade, “Memorandum on Nitrogen products,” 1936, NA, SUPP 3/85, p. 12.

⁵² Ministry of Supply, “War Office Memorandum n°60. Proposed Ammonia Factory,” 1936-40, NA, AVIA 22/1888.

production to around 20 %.⁵³ Before the War, Canada had already emerged as one of the main producers of cyanamide thanks to the vast hydropower resources of the Niagara Falls, but the production of sulphate of ammonia had remained negligible. The production of sulphate of ammonia doubled during the war, and the production of ammonium nitrate was also greatly expanded. Thus, the production of nitrogen in Canada more than trebled in 10 years, from 50,000 tons of nitrogen in 1938-39 to 170,000 tons in 1948-49. In Australia, four government plants were erected in Victoria and New South Wales, with the support of the Australian branch of Imperial Chemical Industries, which operated these plants after the end of the conflict. Their total capacity represented around 50,000 tons of sulphate of ammonia. South Africa mostly produced superphosphate but a small domestic nitrogen industry was also created by the war, with the erection of a synthetic ammonia plant at Modderfontein, issuing around 20,000 tons of sulphate of ammonia a year. Not all this vastly greatly increased capacity was absorbed by the manufacture of explosives, however, and the British government set out to increase fertiliser use among British farmers. This was achieved through such advertising campaigns as “Dig for Victory” or, more directly, through subsidies made to producers, so that by 1949, the British government had spent over £ 12 millions in subsidies. In 1950, the subsidy to producers was discontinued but was replaced a year later by a grant made directly to farmers in order to encourage them to use phosphatic and nitrogenous fertilisers.⁵⁴

The most important long-term consequences of the war was, however, prompted by the need for a much more thorough and comprehensive assessment and planning of nitrogen needs, which further accelerated the integration of the chemical industry and Rothamsted agricultural researchers in the political apparatus. The overall supervision of nitrogen needs was delegated to the Board of Industrial Ammonia Control set up in 1938, and headed by F. C. O. Speyer, Chairman on the British Sulphate of Ammonia Federation. Meanwhile, the government relied on Rothamsted for its information on nitrogen requirements for agriculture, and with the necessities of war, a straightforward formula was devised to quantify the increase in wheat yields which would result from nitrogen application (according to Rothamsted, the application of 35,000 tons of ammonia would result in an increased yield of 350,000 tons of wheat grain).⁵⁵ Many statisticians began working for the Ministry of Supply, and one of their most important contribution was to collect the result of more than 5000 field trials to establish the country's total needs in fertilisers, and to formulate the nation's fertiliser rationing policy. This work was supervised by Crowther and Yates, from Rothamsted, who produced a *Survey of Fertiliser Practice* in 1942, which was thereafter published on a yearly basis.⁵⁶ One of the consequences of the need to monitor and plan nitrogen needs more closely was thus to reinforce the links between the nitrogen industry, the state and agricultural researchers, and to give birth to procedures to quantify nitrogen in order to have a more global vision of needs and resources. This initiated a new national, imperial and

⁵³ Commonwealth Economic Committee, “Survey of the Commercial Fertilizer Industry,” 1950, NA, BT 64/1274; Lammer, *The World Fertilizer Economy*, p. 200 (see note 31).

⁵⁴ Monopolies Commission, *Report on the Supply of Chemical Fertilisers* (London: HMSO, 1959): 29.

⁵⁵ Ministry of Supply, Industrial Ammonia Control, Memorandum by F.C.O. Speyer, “The Case for a New Unit,” 25th November 1940, NA, SUPP14/413.

⁵⁶ J. C. Gower, “Statistics and Agriculture,” *Journal of the Royal Statistical Society, Series A* 151 (1988): 188. The results were compiled in E. M. Crowther and F. Yates, “Fertiliser Policy in War Time. The Fertiliser Requirements of Arable Crops,” *Journal of Experimental Agriculture* 9 (1941): 77-97. Commonwealth Economic Committee, “Survey of the Commercial Fertiliser Industry,” 1950, NA, BT 64/1274.

global form of planning, as the Board of Trade in London and the Combined Food Board in Washington controlled the rationing of fertilizers and issued allocations, even after the end of the conflict. As has been shown in other contexts, the new forms of management that emerged during the war also caused some form of narrowing of vision and the advent of a few standard quantifiable indicators, prompted by the need for agricultural research and policy to simplify ever larger and more distant environments.⁵⁷ Apart from its strategic role in increasing explosive production, nitrogen thus became singled out as the key variable which could be easily quantified and acted upon in order to enact large-scale agricultural transformations.

After WWII, concern over global overpopulation in the colonies, which had gradually emerged in the interwar years, was now much more widely accepted. The voices of Rothamsted soil scientists E. J. Russell and E. M. Crowther were heard beyond their expert fields and the closer integration between political institutions, the chemical industry and Rothamsted survived the end of the war. Thus, when an international association of fertiliser manufacturers, the Fertiliser Society, was created in 1947, Russell was chosen to deliver the inaugural address and Crowther became its President in 1951. Russell became one of the leading soil experts in the new international institutions, where his message for a new global model of high-input agriculture was voiced much more powerfully than before. While the 1930s had been marked by a revived interest in local farming practices, the post-war years witnessed a backlash in the British Empire and the emergence of a more global and uniform model of agricultural modernisation, based on increased mechanisation and a more favourable outlook on chemical inputs, such as pesticides and artificial fertilisers.⁵⁸ After WWII, a new consensus gradually emerged among leading politicians and scientists, who saw organic manures as clearly not up to the task of feeding the colonies and the newly independent nations. Russell, for example, was by then heavily critical of peasant agriculture, which he deemed incapable of feeding the world, and argued that only modernist agriculture, relying heavily on the use of synthetic nitrogen, could sufficiently intensify the world production of food.⁵⁹ Throughout Africa, new fertiliser trials were conducted and the Colonial Advisory Council on Agriculture and Animal Health adopted a more favorable outlook on the development of fertilisers in the continent, while fertiliser use also increased in the West Indies.⁶⁰ Immediately after the War, Crowther was thus asked by the Colonial Office to develop rigorous methods on fertiliser trials, which could be used throughout the Empire to put demonstration and propaganda by district officers on a firmer quantitative basis.⁶¹

⁵⁷ Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley: University of California Press, 2002): 92. See also Theodore M. Porter, *Trust in Numbers: the Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press, 1995) and James C. Scott, *Seeing like a State: How Certain Schemes to Improve the Human Condition have Failed* (New Haven: Yale University Press, 1998) on the idea of simplifying natural environments to make them more “legible”.

⁵⁸ Hodge, *Triumph of the Expert*, p. 233-234 (see note 38). Colonial Development Working Party, “Colonial Supplies and Requirements of Fertilisers,” 14th September 1948, NA, CO 852/876/2; FAO, *The State of Food and Agriculture: 1947* (Geneva: FAO, 1947): 7.

⁵⁹ By the 1950s, Russell had come to believe that even the various attempts at developing composting in India, for example, were superfluous and only fertilisers were “practicable.” E. John Russell, “Asia's Food Problems and Their Impact in the Western Countries,” *International Affairs* 26 (1951): 316-328.

⁶⁰ W. V. Blewett, “Agricultural Developments in Tropical Africa,” *Journal of the Royal Society of Arts* 4827 (1950): 803; Agnes G. Sanderson, *The Agriculture and Trade of the West Indies* (Washington, D.C. : U.S. Dept. of Agriculture, 1961): 1.

⁶¹ E. M. Crowther, “Fertilizer Experiments in Colonial Agriculture,” Colonial Office, *Memoranda on Colonial*

It was primarily in India that nitrogenous fertilisers were gradually becoming isolated as the key to the nation's survival. In 1943, following the famine in Bengal, the Foodgrains Policy Committee had recommended that India take immediate steps to set up a synthetic ammonia plant capable of producing 350,000 tons of sulphate of ammonia a year. A technical mission composed of ICI experts was sent in 1944 and advocated the construction of a plant at Sindri, in Bihar.⁶² Indian civil servants and planners also began to argue that the country needed a "comprehensive programme" to fight against its nitrogen deficiency and that the development of productive capacity would not only provide the country with cheaper fertilisers but would also enable to associate rural development and industrialisation.⁶³ By 1947, India's imports of ammonium sulphate had doubled compared to pre-war figures, domestic production of by-product ammonia had risen to 85,000 tons of nitrogen, and the Sindri factory, set up after the War by a consortium of Anglo-American companies including ICI, was about to be completed. This scheme was followed very closely by the Commonwealth Relations Office since the need for India to import foodstuffs was proving a strain on Great Britain's sterling reserves and India's food self-sufficiency was also seen as the best bulwark against the progress of communism.⁶⁴

When a group of British experts gathered in 1951 to discuss world hunger, it is significant that the question of manuring was treated not by a soil scientist or even a chemist but by a Rothamsted statistician, Frank Yates, who argued that consumption of sulphate of ammonia was still "widely insufficient." From experimental tests based in Great Britain only, Yates was able to devise a formula to quantify future global needs in nitrogen. While he argued that the response to potash and phosphates varied greatly according to the different types of soil, climate or soil, he assumed that nitrogen was the single nutrient whose effects were as uniform as possible. He thus estimated that 1 ton of nitrogen allowed to feed forty more people for a year. This was taken up by Speyer who inferred that, given the current rate of increase in the world's population, global production would have to be increased from 4.5 million tons in 1952 to a little under 60 million tons by the end of the twentieth century. Nitrogen consumption increased dramatically in the 1950s and 1960s, so much so that his prediction was achieved as early as 1980.⁶⁵

Nitrogen had been the primary concern of agricultural chemists since Liebig's law of the minimum and the subsequent controversy between Liebig and Rothamsted's founder, J. B. Lawes, on whether nitrogen had to be supplied or not to plants.⁶⁶ In the first half of the twentieth century, nitrogen was gradually constructed as a global indicator of development, as its ubiquity, its limiting role in food production, as well as the relatively

Fertilizer Experiments (London: HMSO, 1947): 10-28.

⁶² "Memorandum by Imperial Chemical Industries on Fertilisers in India," 4 October 1948, "Imperial Chemical Industries Fertilisers interests in India," NA, DO/142/112.

⁶³ Nabagopal Das, *Agriculture in India: Past, Present, Future* (Calcutta: D. M. Roy, 1944): 42; Radakhamal Mukerjee, *Planning the Countryside, First Report* (Bombay: Hind Kital, 1946): vi.

⁶⁴ Letter by J. Thomson (Commonwealth Relations Office) to W. R. Beswick (Power Gas Corporation), 17 March 1950, NA, DO 142/13.

⁶⁵ Frank Yates, "Manuring for Higher Yields," F. Le Gros Clark and N. W. Pirie, eds., *Four Thousand Million Mouths: Scientific Humanism and the Shadow of World Hunger* (London: Oxford University Press, 1951), 44-73. F. C. O. Speyer, "Reflections on the World Nitrogen Position," *Empire Journal of Experimental Agriculture* 21 (1952): 49-54.

⁶⁶ A. D. Hall, "Agricultural Research in England," *The Contemporary Review* 86 (1904): 675-692.

uniform nature of its effects on yields made it particularly adapted to scientific and political regimes increasingly relying upon abstraction and quantification. In this period, nitrogen was therefore used by scientists and politicians to recast the complex political, cultural, biological, physical, hydrological set of conditions in which food production was embedded into simplified, stable and seemingly universal formulae which equated a given amount of a single chemical element with a corresponding increase in food production. Yet, the story of the development of synthetic nitrogen between the two world wars shows that this can not be recounted only in terms of the progressive and inevitable globalisation of a technology and of a chemical product, and that we should also take into account the complex set of historical processes that enabled the exponential growth of synthetic nitrogen production after WWII.⁶⁷ Expertise between the wars remained multifaceted and ambivalent on the benefits brought about by this new technology and it was only after major crises had made it increasingly adapted to new forms of research and governance that synthetic nitrogen became a global indicator and a standardised solution to agricultural and demographic problems.

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⁶⁷ Bonneuil & Fressoz, *L'événement Anthropocène*, p. 129 (see note 7).

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