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Christine Strotmann*, Laurent Herment and Arnaud Page
**Fertilisers in the Long 19th Century and
Beyond: Usage, Commercialisation and
Production (c 1800–1939)**

**Düngemittel im langen 19. Jahrhundert und
darüber hinaus: Nutzung, Vermarktung und
Produktion (ca. 1800–1939)**

<https://doi.org/10.1515/jbwg-2021-0001>

Abstract: The introduction to the volume provides an overview of processes in the industrialization of agriculture in the 19th and 20th centuries with regard to fertilisation. It explains the interplay between the intensification of fertiliser usage and agricultural output which enabled immense population growth. It shows how chemical discoveries surrounding nitrogen, potassium and phosphorus (NPK) eventually led to a diversification of markets and the formation of big fertiliser businesses. Indeed, every specific fertiliser chain was linked to a wide set of markets and institutions, as to stakeholders with various and potentially conflicting interests. This issue aims to shed light on this aspect within several regions across Europe and beyond.

JEL-Codes: N 00, N 10, N 50, O 13

Keywords: Düngemittel, Wirtschaftsgeschichte, Industrialisierung, Agrarwirtschaft, Chemie, fertiliser, economic history, industrialization, agriculture, chemistry

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1 Thematic Introduction

Between 1900 and 2020, world population has more than quadrupled from 1.6 billion to 7.8 billion. According to some projections, this figure will increase to as much as 10.5 billion people by 2050. This population explosion would never have been possible without the development of artificial fertilisers, which, along with developments in plant breeding and chemical *protection* (herbicides, pesticides, etc.), played a major role in the tremendous yield increases which occurred in the 20th century: average wheat yields per hectare increased three times in the US and nearly four in China, while rice yields in Japan almost trebled in the same time span.¹ In this context of rising population and demand for fertilisers, they have been, and will continue to be, indispensable to feeding the growing world population, a problem further compounded by changes in dietary patterns. Demand for fertilisers currently keeps growing at a rate of around 1.5 percent per year, even though aggregate figures of course hide very important regional disparities.² Not surprisingly there is a strong connection between the level of industrialization a country is at and its fertiliser usage, historically and currently. The very usage of off-farm fertilisers is both a practice arising from and a sign of the market integration of agriculture in a country or region. The necessity to bring *external* plant nutrients into an otherwise circular agriculture arose with urbanisation: food transports into the cities meant that plant nutrients left the agricultural cycle and were not restored, unless the farms were fertilised using sewage from the cities in turn.³ Hence the increased use of fertilisers in any agricultural economy is intertwined with industrialization on two levels: their usage is both made necessary and possible by it.

Yet, despite the positive effects of increased yields, the extended usage of fertilisers has had negative effects that are obvious in modern debates about industrialized agriculture: apart from the non-renewable nature of phosphorus

1 V. Smil, Nitrogen Cycle and World Food Production, in: World Agriculture 2/1, 2011, pp. 9-13.

2 FAO, World Demand for Nitrogen, Phosphorus and Potassium for Fertiliser Use, 2016-2022, in: World Fertiliser Trends and Outlook to 2022, Rome 2019, <http://www.fao.org/3/ca6746en/CA6746EN.pdf>, 17.10.2020. The three top consumers (China, the US, and India) together account for 50 percent of the global consumption of fertilisers. Estimates suggest that the diet of an average American consumes almost ten times as much nitrogenous fertilisers as that of a Tanzanian. M.J. Ibarrola-Rivas/S. Nonhebel, Variations in the Use of Resources for Food: Land, Nitrogen Fertiliser and Food Nexus, in: Sustainability 8/12, 1322, 2016, <https://www.mdpi.com/2071-1050/8/12/1322/htm>, 07.01.2021.

3 G. Mahlerwein, Grundzüge der Agrargeschichte, Volume 3: Die Moderne (1880-2010), Köln 2016, p. 104.

reserves, the strong dependency of other fertilisers on energy, often from fossil fuels, and the creation of a form of *chemical dependency* among farmers, the increased use of fertilisers has had many detrimental effects, in particular the pollution of water resources, eutrophication and emissions of nitrous oxide (N₂O), a very potent greenhouse gas.⁴

There is little doubt that the increasing use of fertilisers has been a defining feature of the last 200 years, and has greatly shaped not only agrarian but also industrial and economic systems. The basic elements in the story of fertilisers are by now well known. If the use of manures and other forms of fertilising substances is as old as agriculture, the modern era of off-farm *chemical* or *artificial* fertilisers, is generally traced back to the 1840s. In that decade, a group of agricultural chemists recast plant nutrition as a *chemical equation*, in which plant growth depended on the absorption of key nutrients, mostly nitrogen, phosphorus and potassium (NPK).

Already in 1802, the German geographer, naturalist and traveller Alexander von Humboldt had taken guano samples from Peru and brought them to Europe. The bird dung, containing nitrogen and phosphorus, had been used as fertiliser by people in its region of origin for centuries and would – with the newfound knowledge about plant nutrients – open the gates to an off-farm fertiliser market in Europe, but only four decades after Humboldt's trip to South America.⁵ Around the same time as Humboldt first brought guano to Europe, Albrecht Daniel Thaer, a German doctor and farmer, was the first to cautiously connect agriculture with the discourse of chemistry. He emphasized the circularity of nutrition processes in the whole living world, the importance of chemical elements in plants and, finally, postulated a proportional relationship between the size of a harvest and the amount of “nutrient juices” plants take from the soil.⁶ But the real rupture occurred between 1830 and 1850 with the works of, among others, Boussingault in France, Liebig in Germany, Lawes and Gilbert in Great Britain, who highlighted the roles of nitrogen, phosphorus and potassium, the most essential plant nutrients.

4 See for example A. Muller *et al.*, Strategies for Feeding the World more Sustainably with Organic Agriculture, in: Nature Communications 8, 2017, <https://www.nature.com/articles/s41467-017-01410-w>, 07.01.2021; G. Billen *et al.*, Two Contrastred Future Scenarios for the French Agro-food System, in: Science of The Total Environment 637/638, 2018, pp. 695-705.

5 B. Rott, Alexander von Humboldt brachte Guano nach Europa – mit ungeahnten globalen Folgen, in: International Review for Humboldt Studies 32, 2016, pp. 82-109, <https://doi.org/10.18443/234>, 17.10.2020.

6 A.D. Thaer, Grundsätze der rationellen Landwirtschaft, Bd. 2, Berlin 1812, pp. 293, 463.

Notably many chemists also produced and sold their own fertilisers at some stage. These scientific developments coincided with the rise of the manure trade. In 1841, the first shipment of Peruvian guano (bird excrements containing a large proportion of nitrogen) landed in Great Britain. The use of guano then rapidly spread in Western Europe and the United States. With declining stocks and quality, the guano trade was then gradually replaced by another South American commodity, nitrates found in the Atacama Desert (Chile),⁷ as well as sulphate of ammonia, a by-product of the coal industry. By 1912, these two forms of inputs came to represent respectively two thirds and one third of the world production of nitrogenous fertilisers.⁸ The First World War was a turning point in the history of nitrogenous fertilisers, since in 1913, the Haber-Bosch process, which made it possible to *fix* atmospheric nitrogen to produce ammonia, was developed in Germany. The process, which has been called the “most important invention of the twentieth century”,⁹ was then used to manufacture fertilisers, as well as explosives, which also require nitrogen, on so massive a scale that the interwar period witnessed acute problems of nitrogen overproduction. After the Second World War and developments in plant breeding which resulted in new high-yielding varieties of wheat and rice that were more responsive to nitrogenous fertilisers, the consumption of fertilisers increased very rapidly: around 1910, *artificial* nitrogen (including Chilean nitrates, guano and sulphate of ammonia) represented roughly 0.5 million tons of nitrogen, which had risen, thanks to the development of the Haber-Bosch process, to more than 3 million tons before the Second World War, over 30 million tons in 1970, and more than 100 million tons of nitrogen in 2010.¹⁰ The scale of this increase and of contemporary consumption illustrates how much modern agriculture has come to depend upon synthetic nitrogen, the stocks of which are inexhaustible, but which comes with a wide array of detrimental environmental effects.

As for phosphates (P), the use of bones, in particular charred bones, had been known for a long time but a new process was developed in the early 1840s, in particular by the British chemist John Bennet Lawes, of treating bones with sulphuric acid to manufacture “superphosphate”. In the late 19th century, the use of bones and coprolites (fossilized faeces) was rapidly superseded by the use of basic slag, a by-product of the steel industry, but more importantly of rock phos-

⁷ Originally the beds of nitrate were located in Peru and Bolivia, but after the Pacific war, Chile gained control of the main deposit.

⁸ *UK Ministry of Munitions of War*, Report of the Nitrogen Products Committee, London 1919, p. 16.

⁹ V. Smil, Detonator of the Population Explosion, in: *Nature* 400, 1999, p. 415.

¹⁰ *Idem*, Nitrogen Cycle.

phate, which started to be mined first in South Carolina (1867) and Florida (1890), in France and in Belgium as well but mostly in Algeria, Tunisia, Nauru in the 1900s, and then in Morocco at the end of the First World War.¹¹ By the late 1930s, the United States and French colonies in the Maghreb each produced around 35 percent of the world's rock phosphate, and Nauru around 10 percent.¹² The consumption of phosphorous fertilisers then leapt from less than 5 million tons a year in the 1960s (in million tons phosphorus, P) to almost 20 million tons nowadays.¹³ Today, the United States are still the largest producer of phosphates in the world, but it is estimated that more than 70 percent of the world's reserves are located in Morocco alone, and the question of a coming "peak phosphorus" has been the subject of a heated controversy over the last ten years.¹⁴

The third vital plant nutrient, potassium (K), was, until the middle of the 19th century, primarily provided to plants through the use of wood ashes, supplemented by a few other minor sources, such as kelp (burnt algae). The global industry in wood ashes then came to a sudden halt when potash (potassium chloride, K₂O) mines were opened in Stassfurt, Germany in the early 1860s, which gave the German Kalisyndicate a monopoly over the global trade in potash.¹⁵ After the First World War, Germany continued to dominate the trade, but France also became an important actor, thanks to the recovery and development of deposits located in Alsace, while a few other countries, such as the USA, developed a small local industry so as to curtail their dependence upon imports. After the Second World War, the Stassfurt and other potash mines

11 K. Ashley/D. Cordell/D. Mavinic, A Brief History of Phosphorus: From the Philosopher's Stone to Nutrient Recovery and Reuse, in: *Chemosphere* 84, 2011, pp. 737-746; M. Dixon, Chemical Fertiliser in Transformations in World Agriculture and the State System, 1870 to the Inter-war Period, in: *Journal of Agrarian Change* 18/4, 2018, pp. 768-786.

12 Calculated from U.S. Department of the Interior, World Production of Phosphate Rock from 1935 to 1939, in: *Minerals Yearbook*, Washington 1940, p. 1316.

13 C. Lu/H. Tian, Global Nitrogen and Phosphorus Fertiliser Use for Agriculture Production in the Past Half Century: Shifted Hot Spots and Nutrient Imbalance, in: *Earth System Science Data* 9/1, 2017, pp. 181-192.

14 D. Cordell/J.O. Drangert/S. White, The Story of Phosphorus: Global Food Security and Food for Thought, in: *Global Environmental Change* 19/2, 2009, pp. 292-305; J.D. Edixhoven/J. Gupta/H.G. Savenije, Recent Revisions of Phosphate Rock Reserves and Resources: a Critique, in: *Earth System Dynamics* 5, 2014, pp. 491-507.

15 D. Ciceri/D. Manning/A. Allanore, Historical and Technical Developments of Potassium Resources, in: *Science of The Total Environment* 502, 2015, pp. 590-601. The main product from the German mines was first potassium chloride, then from 1890, kainite became another major product.

became an important economic factor in the GDR¹⁶, while other countries started to develop their own potash industries, such as Russia, and more importantly Canada, which came to dominate the world market: today Canada, Russia and Belarus produce more than 60 percent of world consumption.¹⁷

2 Literature

But beyond these broad-brush stories and the magnitude of these figures, historians in the past few decades have explored a number of issues related to the increasing use of fertilisers. It is beyond the scope of this introduction to provide a full review of the historiography of fertilisers, but one may mention here a few of its important features. Naturally rural historians have paid attention to the question of manuring and the maintenance of the fertility of soils during the early modern period and the 19th century in Europe.¹⁸ The question of land fertilising has also been approached by historians working on the question of the recycling of urban and industrial matters in agriculture, focusing mostly on the debate on public hygiene in towns rather than on the use of these fertilising materials by farmers.¹⁹

16 G. Duchrow, Der 100-jährige „Rhönmarsch“ in die Kohlensäurefelder des südthüringischen Kalibergbaues, in: *Der Anschnitt* 49/4, 1997, p. 123-147; *Idem*, Kalibergbau im Südharz-Unstrut-Revier – die ersten und die vorerst letzten Aktivitäten, in: *Der Anschnitt* 48/5-6, 1996, p. 178-194; *Idem*, Die bergtechnische Entwicklung des Kalisalzbergbaus der DDR, in: *Glückauf* 126/21, 1990, S. 1016-1033; K.-H. Hauske/D. Fulda (Eds.), *Kali. Das bunte, bittere Salz*, Leipzig 1990. We would like to thank Reinhold Reith for this information.

17 Source FAO statistics, available at: <http://www.fao.org/faostat/en/#data/RFN>, 17.10.2020.

18 G.P.H. Chorley, The Agricultural Revolution in Northern Europe, 1750-1880: Nitrogen, Legumes, and Crop Productivity, in: *The Economic History Review* 34/1, 1981, pp. 71-93; G. Cunfer, Manure Matters on the Great Plains Frontier, in: *The Journal of Interdisciplinary History* 34/4, 2004, pp. 539-567; R.S. Shiel, Improving Soil Productivity in the Pre-Fertiliser Era, in: *B.M.S Campbell/M. Overton (Eds.), Land, Labour and Livestock*, Manchester 1991, pp. 51-77; D. Helms, Soil and Southern History, in: *Agricultural History* 74/4, 2000, pp. 723-758; R.C. Allen, The Nitrogen Hypothesis and the English Agricultural Revolution: A Biological Analysis, in: *The Journal of Economic History* 68/1, 2008, pp. 182-210; L. Brunt, Where There's Muck, There's Brass: The Market for Manure in the Industrial Revolution, in: *The Economic History Review* 60/2, 2007, pp. 333-372.

19 J.A. Tarr, From City to Farm: Urban Wastes and the American Farmer, in: *Agricultural History* 49/4, 1975, pp. 598-612; E. Marald, Everything Circulates: Agricultural Chemistry and Recycling in the Second Half of the Nineteenth Century, in: *Environment and History* 8/1, 2002, pp. 65-84; S. Barles, *L'invention des Déchets Urbains: France, 1790-1970*, Seyssel 2005; D.

For the post-1840 period, one of the most researched topics has been the history of the rise of a more *scientific* form of agriculture, and of the development of an infrastructure of scientific advice, in particular in Europe and in the United States.²⁰ Historians have obviously, and for several decades now, paid attention to the development of the trade in the most important commodities, such as guano,²¹ nitrates,²² or phosphates,²³ and, more generally, to the globali-

Simmons, Waste Not, Want Not: Excrement and Economy in Nineteenth-Century France, in: *Representations* 96/1, 2006, pp. 73-98; *S. Gierlinger et al.*, Feeding and Cleaning the City: the Role of the Urban Waterscape in Provision and Disposal in Vienna during the Industrial Transformation, in: *Water History* 5/2, 2013, pp. 219-239; *M.W. Gray*, Urban Sewage and Green Meadows: Berlin's Expansion to the South 1870-1920, in: *Central European History* 47/2, 2014, pp. 275-306; *F. Uekötter*, City meets Country. Recycling Ideas and Realities on German Sewage Farms, in: *Journal for the History of Environment and Society* 1, 2016, pp. 89-107; *L. Herment*, Vidanges et Fertilisants. Le Cas de la Poudrette Parisienne au Milieu du Dix-Neuvième Siècle, in: *Journal for the History of Environment and Society* 2, 2017, pp. 95-126, and the introduction by L. Herment and T. Le Roux in that special issue.

20 Among the numerous publications on this topic see *A.I. Marcus*, *Agricultural Science and the Quest for Legitimacy*, Ames 1985; *M.R. Finlay*, *The German Agricultural Experiment Stations and the Beginnings of American Agricultural Research*, in: *Agricultural History* 62/2, 1988, pp. 41-50; *L. Ferleger*, *Arming American Agriculture for the Twentieth Century: How the USDA's Top Managers Promoted Agricultural Development*, in: *Agricultural History* 74/2, 2000, pp. 211-226; *N. Jas*, *Au Carrefour de la Chimie et de l'Agriculture: Les Sciences Agronomiques en France et en Allemagne, 1840-1914*, Paris 2001; *D. Fitzgerald*, *Every Farm a Factory: The Industrial Ideal in American Agriculture*, New Haven 2003; *L. Diser*, *Laboratory versus Farm: The Triumph of Laboratory Science in Belgian Agriculture at the End of the Nineteenth Century*, in: *Agricultural History* 86/1, 2012, pp. 31-54; *P. Jones*, *Agricultural Enlightenment*, Oxford 2016.

21 *W.M. Mathew*, *The House of Gibbs and the Peruvian Guano Monopoly*, London 1981; *J. Skaggs*, *The Great Guano Rush: Entrepreneurs and American Overseas Expansion*, New York 1994; *H. Snyders*, 'Stinky and Smelly' but Profitable: The Cape Guano Trade, c.1843-1910, 2011 https://www.academia.edu/1409527/_Stinky_and_smelly_but_profitable_the_Cape_guano_trade_c_1843_1910, 07.01.2021; *G. Cushman*, *Guano and the Opening of the Pacific World: A Global Ecological History*, Cambridge 2013.

22 *R. Miller/R. Greenhill*, The Peruvian Government and the Nitrate Trade, 1873-1879, in: *Journal of Latin American Studies* 5/1, 1973, pp. 107-131; *T.F. O'Brien*, The Antofagasta Company: A Case Study of Peripheral Capitalism, in: *The Hispanic American Historical Review* 60/1, 1980, pp. 1-31; *M. Monteón*, John T. North, the Nitrate King, and Chile's Lost Future, in: *Latin American Perspectives* 30/6, 2003, pp. 69-90.

23 *N. Dougui*, *Histoire d'une Grande Entreprise Coloniale. La Compagnie des Phosphates et du Chemin de Fer de Gafsa, 1897-1930*, Tunis 1995; *S.W. McKinley*, Stinking Stones and Rocks of Gold: Phosphate, Fertiliser, and Industrialization in Postbellum South Carolina, Gainesville 2014; *K. Teaiwa*, Ruining Pacific Islands: Australia's Phosphate Imperialism, in: *Australian Historical Studies* 46/3, 2015, pp. 374-391.

zation of commodity chains which went along with the development of artificial fertilisers.²⁴

Much attention has also been devoted to the history of the chemical industry, in particular that of nitrogen synthesis.²⁵ Recently, historians have also started to pay closer attention to the various forms of coerced labour and labour regimes attendant upon the development of this trade.²⁶ A more critical current has also focused on the history of fertilisers to shed light on the history of appropriation of *unpaid work/energy*, and of *metabolic rifts*.²⁷ Finally, in the last 20 years, following the work of Georgescu-Roegen and Vaclav Smil, a very lively field of research has been devoted to the quantification of energy and nutrient flows in agricultural history.²⁸

24 R. Miller/R. Greenhill, The Fertiliser Commodity Chains: Guano and Nitrate, 1840-1930, in: S. Topik/C. Marichal/Z. Frank (Eds.), *From Silver to Cocaine. Latin American Commodity Chains and the Building of the World Economy, 1500-2000*, Durham 2006, pp. 228-270.

25 G. Ertl, Der mühsame Weg zum Haber-Bosch-Prozess und dessen Mechanismus, in: G. Ertl/J. Soentgen (Eds.), *Stickstoff – ein Element schreibt Weltgeschichte*, München 2015, pp. 161-168; J.A. Johnson, Die Macht der Synthese (1900-1925), in: W. Abelshauser (Ed.), *Die BASF. Eine Unternehmensgeschichte*, München 2002, pp. 117-220; M. Szöllösi-Janze, Losing the War, but Gaining Ground: The German Chemical Industry during World War I, in: John E. Lesch (Ed.), *The German Chemical Industry in the Twentieth Century*, Dordrecht 2000, pp. 91-121; V. Smil, *Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production*, Cambridge 2000; G.J. Leigh, *The World's Greatest Fix: A History of Nitrogen and Agriculture*, Oxford 2004; H. Gorman, *The Story of N: a Social History of the Nitrogen Cycle and the Challenge of Sustainability*, New Brunswick 2013; A. Page, *The Greatest Victory which the Chemist has won in the Fight (...) against Nature: Nitrogenous Fertilisers in Great Britain and the British Empire, 1910s-1950s* in: *History of Science* 54/4, 2016, pp. 383-398; A.S. Travis, *Nitrogen Capture: The Growth of an International Industry (1900-1940)*, Cham 2018.

26 T.W. Schick/D.H. Doyle, The South Carolina Phosphate Boom and the Stillbirth of the New South, 1867-1920, in: *South Carolina Historical Magazine* 86/1, 1985, pp. 1-31; E. Melillo, The First Green Revolution: Debt Peonage and the Making of the Nitrogen Fertiliser Trade, 1840-1930, in: *American Historical Review* 117/4, 2012, pp. 1028-1060; S. Jackson, The Phosphate Archipelago: Imperial Mining and Global Agriculture in French North Africa, in: *Jahrbuch für Wirtschaftsgeschichte/Economic History Yearbook* 2016/1, pp. 187-214.

27 B. Clark/J.B. Foster, Ecological Imperialism and the Global Metabolic Rift: Unequal Exchange and the Guano/Nitrates Trade, in: *International Journal of Comparative Sociology* 50/3-4, 2009, pp. 311-334; M. Dixon, Chemical Fertiliser in Transformations in World Agriculture and the State System, 1870 to the Interwar Period, in: *Journal of Agrarian Change* 18/4, 2018, pp. 768-786.

28 N. Georgescu-Roegen, *The Entropy Law and the Economic Process*, Cambridge 1971; F. Krausmann, Milk, Manure, and Muscle Power. Livestock and the Transformation of Preindustrial Agriculture in Central Europe, in: *Human Ecology* 32/6, 2004, pp. 735-772; E. Tello et al., The Onset of the English Agricultural Revolution: Climate Factors and Soil Nutrients, in: *Jour-*

3 Questions/aims of this volume

If we thus now know much more about the general and global history of fertilisers, paradoxically, the commercialization, the concrete practices, the experimentations and the diffusion of knowledge among farmers deserve much more study. This special issue wishes to add to the research mentioned above by attempting to combine some of their perspectives, in order to better understand the practices of the firms and public authorities which were involved in the production and commercialization of fertilisers. Its aim is to contribute to a greater understanding of one of the major elements in the “first green revolution” of the 19th and 20th centuries and the structures behind it. It deals with the stakeholders in the field of fertilisers: producers and traders, states and farmers, with a focus being placed on markets and policies. The case studies in this volume cover Germany, Great Britain, France, Spain and Australia and focus on different types of fertilisers: guano, nitrates, leguminous plants, seedcakes, in addition to mineral phosphates and artificial nitrogenous fertilisers. The juxtaposition of these analyses, many of which are by researchers still early on in their careers, helps to uncover the uneven process of fertiliser use intensification but also the interconnectedness of markets. An essential dimension of the fertiliser trade during the 19th century and the interwar period studied in different articles of this special issue is that commercial-industrial endeavours took place on a global scale, yet very often within the context of national or colonial economies, and included the blatant exploitation of men and nature, as well as commercial firms and industrialists. The whole planet was mustered to provide fertilisers to European and neo-European regions.²⁹

The examination of each fertiliser as a specific commodity, belonging to a specific commodity chain, put in place by a specific company, cannot apprehend the complexity of the trade of fertilisers. Indeed, every specific fertiliser chain was linked to a wide set of markets and institutions, and stakeholders with various and potentially conflicting interests (scientists, firms, farmer’s union or

nal of Interdisciplinary History 47/4, 2017, pp. 445-474; E. Tello et al., Opening the Black Box of Energy Throughputs in Farm Systems: A Decomposition Analysis between the Energy Returns to External Inputs, Internal Biomass Reuses and Total Inputs Consumed (the Vallès County, Catalonia, c; 1860 and 1999), in: Ecological Economics 121, 2016, pp. 160-174; J. Le Noé et al., Long-Term Socioecological Trajectories of Agro-Food Systems Revealed by N and P Flows in French Regions from 1852 to 2014, in: Agriculture, Ecosystems & Environment 265, 2018, pp. 132-143.

²⁹ A.W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900-1900*, Cambridge 1986.

cooperatives, and finally the state). To grasp this complexity and the multiple links between industrial and commercial networks and other stakeholders (scientists, farmers, states), it may be better to use the notion of “commodity web” rather than that of “commodity chain”.³⁰ As shown by Andreoni in this issue, oilseeds, as fertilisers, were part of a “nitrogen fertiliser web”, but as cattle feeding stuffs they were part of a “cattle-breeding and dairying web”. These two webs involved not only farmers, but firms and scientists as well, and finally states which had to regulate quality, prices and tariffs. These two webs spread across the whole planet from Chile, which produced sodium nitrate, to Great Britain, Germany, Belgium, and France, producing sulphate of ammonia, from Russia, Argentina, the USA and India producing linseed, to Western Africa and India which produced peanuts, etc. They then linked firms which produced a large set of commodities with nutrition scientists and agricultural chemists, with farmers in Europe, Asia, Africa, and North and South America, and tariff policies of European states.

This diversity of cases complicates the simple narrative according to which *artificial* fertilisers *naturally* replaced *organic* fertilisers after the First World War. This volume reveals a more complex and nuanced view, emphasizing not the replacement of *old* by *new*, but a continuous process of intensification, where the *organic*, the *mineral* and the *artificial* coexisted and the borders between them sometimes blurred (Andreoni, Corbacho). Rather than focus on new *discoveries*, this special issue tries to look at the practical challenges (industrial, commercial, etc.) faced by the producers and sellers of fertilisers. The replacement of *organic* by *artificial* products was rarely, if ever, due to a preference for the *artificial*, as this gradual and uneven shift was in large part dependent on availability, prices, marketing and advertisement (Moss, Strotmann), on the devising of new conceptions of fertiliser value (Herment and Page), as well as on state support and regulation (Byerlee, Llopart), and other arrangements, such as cartels, to structure markets (Moss, Llopart).

Another theme that this special issue addresses in several articles is the part played by scientists in the propagation of fertilisers. Agronomists and chemists obviously had a major role in this, but it was rarely one of uncritical and blind promotion. Until the Second World War, most scientists would indeed not have considered that farmyard manure could be entirely dispensed with and wholly replaced by artificial fertilisers. The role of scientists in the spread of fertilisers thus lay probably not so much in an unequivocal promotion of fertilisers than in

³⁰ J. MacFadyen, *Flax Americana: A History of the Fibre and Oil That Covered a Continent*, Montreal 2018, pp. 18-19.

setting up an infrastructure of research, measurement and collection of data which could then be used by farmers and private companies to assess and promote the benefits of fertilisers.

The history of fertilisers provides a case where science and trade are inseparable, but science also heavily influenced policy making as it began to regulate markets. As several articles in this special issue evoke, the most important role of political institutions in the development of the fertiliser trade was in the passing of legislation on quality. By 1900, several European countries, with some exceptions (including Germany and the Netherlands), had enacted laws, decrees, statements, to build trust and protect farmers against fraud in fertilisers or animal feedstuffs.³¹ These pieces of legislation, which created a regulatory framework for fertilisers and appointed inspectors to monitor the quality of products sold, played a fundamental role in building farmers' confidence in a trade that had supposedly until then been ridden with mistrust and allegations of various forms of fraud and adulteration.³²

At the same time, the fact that agricultural chemistry made farming increasingly appear as such an easy input/output story, also appealed to political planners, and helped it trump over soil sciences. After the First World War, states thus took on a much more active role by taking over resources building trust, controlling resources and production processes, and implementing export bans and tariffs.³³ Several articles in this special issue indeed show that the increasing use of fertilisers was not only due to their agricultural properties but also to their strategic dimension for the state (Llopert, Byerlee) and to their adaptation to new conceptions of what constituted good agriculture (Herment and Page, Strotmann).

31 For example, Portugal (1889), Norway (1890), Great Britain (1893), South Australia (1894), Denmark (1898) and Spain (1900).

32 As in the case of food regulation (1905 legislation in France for example), these regulations were promoted by some industrialists too, who were concerned by the market disturbance induced by fraud and adulteration. The enactment of such a law implied setting up institutions to control the trade, in particular through analytic laboratories, which were partly or fully funded by the state. See A. Stanziani, *La Qualité des Produits en France (18e-20e siècles)*, Paris 2003.

33 F. Uekötter, Why Panaceas Work: Recasting Science, Knowledge, and Fertilizer Interests in German Agriculture, in: *Agricultural History* 88/1, 2014, pp. 68-86.

4 Summaries of articles

If most histories of *artificial* fertilisers begin in the 1840s, there are in fact considerable difficulties involved in postulating the existence of a clear watershed in this process. The success of animal bone char in western France needs to be linked to the success of the market for off-farm manure in inland Flanders from the 18th century as demonstrated recently by Pieter De Graef.³⁴ The article by Corbacho and al. in this issue reminds us that European farmers first tried to overcome the limits of their agrarian systems in an organic agriculture framework. It thus shows that there was no clear-cut separation between a pre- and post-fertilising era. In other words, there could be intensification within an organic framework, but it resulted in the end in soil mining and resource depletion. In the case of Galicia, peasants faced a decline of potassium and probably of phosphates too. But the Galician case is interesting because it proves that it was not only in the advanced agricultural regions of North-East Europe that farmers were concerned with the maintenance of fertility to deal with the intensification of agriculture (not only on arable lands but within the entire agrarian system including pasture, forestry and cattle breeding). The Galician case thus illustrates that the willingness and capability of farming communities were not always sufficient to solve the problems raised by the intensification of agriculture and soil mining.

The article by Arnaud Page and Laurent Herment demonstrates how scientists played an important role in producing and disseminating knowledge about fertilisers. As soon as fertilisers became *commercial*, their price became a crucial issue, and a concern for farmers and governments. The problem was to find a way to assess the monetary value of a material, the fertilising value of which was not always clearly identified. Scientists played a major role in the commodification of fertilisers, not simply because they discovered and popularized the agronomic value of commercial fertilisers, but because some of them argued that fertilising value, measured by the percentage of fertilising compounds they contained (nitrogen, phosphates and potassium), could be used to determine the price of fertilisers. Devising an abstract price for nitrogen could then be used to determine the price differential between two very different forms of nitrogenous fertilisers (ammonium sulphate and sodium nitrate). This was not a means to assess the exact value of nitrogen, but to assess the relative value of all ni-

³⁴ P. De Graef, The Peasant Route to Innovation: Fertiliser Improvement in the Smallholding Economy of Eighteenth-Century Flanders, Belgium, in: *Agricultural History* 91/4, 2017, pp. 488-512.

trogenous fertilisers, irrespective of their material dimension or geographical provenance. The same thing occurred with phosphoric acid and potash, but what is particularly noteworthy in the case of nitrogen is the fact that the chemical element itself gained a value during this process.³⁵ This example also shows that if there were a few scientists, like Georges Ville in France or J.C. Nesbit in Great Britain, who assessed the value of fertilisers strictly based on their chemical constituents and thus advocated for the replacement of farmyard manure by more concentrated and stable *artificial* fertilisers, most scientists remained on the whole very cautious about these radical forms of chemical reductionism. Science in other words, mostly played a role in measuring and producing quantitative data which could then be used by other actors to provide indications on the profitability of fertilisers.

The work of Derek Byerlee on Australia also explores how scientific institutions like the Central Agricultural Bureau in South Australia at the end of the 19th century provided farmers with scientific and economic data to compare the yield increases produced by various applications of superphosphate and their corresponding costs, but also how these institutions were hybrid entities associating government scientists and farmers. Farmers could thus collaborate with scientists in order to counter the attempt of manufacturers to build monopolies and *corner* markets. Farmers even sometimes became fertiliser manufacturers themselves, as in the Phosphate Cooperative Company of Australia (1919) which emerged as the largest manufacturer of superphosphate in Australia. Byerlee's article also illustrates the debates regarding governmental intervention following the First World War, by studying the conflict between manufacturers, who campaigned for tariffs on imported superphosphate, and farmers keen on benefiting from cheap phosphate. After having unsuccessfully campaigned for tariff protection before the First World War, the manufacturers eventually obtained the creation of a tariff on imported superphosphate in 1921, which farmers strongly contested throughout the 1920s, as prices of superphosphate in Australia were considerably higher than in the rest of the world. With the onset of economic depression in the early 1930s, sales of superphosphate sharply dropped, which the government tried to remedy with the passing of a subsidy on superphosphate from 1933 onwards.

³⁵ There were of course prices for gold, etc. but the price refers to a metal, not to a chemical element. Phosphoric acid and potash were also given abstract prices, but these were compounds, not elements. From this point of view, it was not only the price of fertilisers which depended on chemical analysis. The price of beetroot also came to be, at the same time, mostly determined by its sugar content.

By focusing on Edward Packard, a British phosphate manufacturer, who was instrumental in the creation and activities of the Fertiliser Manufacturers' Association (FMA), Michael Moss examines in his article how, from the 1870s, British fertiliser manufacturers organised themselves in order to shore up their profits and to fight against declining prices. Fertiliser manufacturers initially associated themselves to be able to bear on legislative activity (regarding both environmental and trading regulations) and to regulate prices, mostly through local associations which tried to fix production quotas and negotiate floor prices. As Moss shows, however, these attempts in the late 19th century were largely unsuccessful with some companies refusing to participate in these organisations and underselling their products. Even more preoccupying for the manufacturers was competition from foreign fertiliser companies. Since British manufacturers could not benefit from tariff barriers, the activities of the Association mostly revolved around collectively buying up imports in order to control prices. After the First World War, this policy was discontinued, and so were the attempts at fixing regional prices or production quotas. At a global level, Edward Packard was also involved in the creation of the International Superphosphate Manufacturers' Association (in 1926), which suffered the same fate, and similarly dropped the idea of being able to fix world prices and share markets, to fall back on promoting the use of superphosphate and encouraging information exchange between its members. State involvement in the fertiliser trade also occurred through the setting of tariffs and export bans to protect these strategic industries. As Moss concludes, the British government thus forbade the exportation of superphosphate during the First World War except to British colonies. However, after the war, and despite pleas by the FMA, the British government refused to impose a tariff on imported superphosphate, for fear that it would lead to higher prices for farmers.

Luca Andreoni demonstrates that the modernisation of agriculture not only involved practices of fertilisation on arable land for wheat, sugar beetroots, potatoes and the like, but also cattle-breeding and dairy production. The example of oilseed cakes allows us to link the two major issues that European farmers faced at the time: increasing yields in arable production and increasing yields in animal production, and oilseed cakes played a role in both. As Andreoni shows, although oilcakes were primarily meant as cattle feed, a significant share of oilseed cakes, in particular non-edible ones, were used as fertilisers (around 20 percent of the trade going on in Marseilles in the 1920s was thus used as fertiliser). Andreoni also reveals how, in the early 1930s, farmers seem to have used oil seedcakes as a replacement for artificial fertilisers, thus illustrating that the history of fertilisers is not simply the gradual replacement of organic by

synthetic manures. Andreoni's article also sheds light on the vagaries of state intervention in the fertiliser and feeding stuffs market. It thus contrasts the relatively minor interventionism of the Italian government with the more proactive and politically controversial attitude of the French government, which introduced a ban on the exportation of seedcakes in the 1920s as a way to keep these inputs on domestic territory and to control their prices. This ban and other forms of market regulation were periodically relaxed to appease the manufacturers and to reflect changing market conditions, but overall the interwar period was characterized by substantial governmental intervention in order to ensure that farmers had cheap access to seedcakes.

While scientists played a role in the dissemination of knowledge concerning fertilisers, it was accompanied by significant efforts by manufacturers and industrialists to promote and advertise their products, and fertiliser advertisements played a very important role in their diffusion. Christine Strotmann's article examines the peculiar dynamics in Germany, where during the First World War capacities to synthetically fix nitrogen were expanded drastically. This led to tension between its producers, most notably those of ammonia and nitro-lime, and in the aftermath of the war also between the merchants eager to reintroduce chile-saltpetre to the German market. So the state, which had heavy (financial) interests in all factories producing nitrogenous products had to act as an intermediary, not only between the producers but also between the producers and agricultural interests. The simple strategy was to encourage farmers to use as much nitrogenous fertilisers as possible. Obviously the practice had limits, notably within the boundaries of the economics of farming, and specifically during the tumultuous postwar period, in which food supply was notoriously short and hence government had a keen interest in keeping production up while maintaining low prices for the consumer. In fact, it was close to impossible for German agriculture to buy and use all the fertiliser produced in the country from the mid-1920s onwards, and so antagonism amongst the fertiliser producers increased notably. This article shows that even as economic circumstances – partially and periodically – improved, the nitrogenous fertiliser market remained segregated notwithstanding its cartelisation in 1919.

Yet, the German nitrogen industry was not unique in its cartelisation: Michael Llopart's article also reveals how the state was in fact always having to maintain a difficult balance between manufacturers' and farmers' interests. The creation of associations and cartels was very effective for nitrogenous fertilisers, especially during the interwar period. In France, as explored in Llopart's article, the *Comptoir Français de Sulfate d'Ammoniaque* (founded in 1907) which later became the *Comptoir Français de l'Azote* (1920) was a rather successful initiative

of the most important sulphate of ammonia producers to pool together their advertising and sales resources. This *cartelisation* of the nitrogen industry was precisely what led the French government to fund the *Office national industriel de l'azote* (ONIA), in order to avoid this great nitrogen *trust* from fixing prices. At the international level, the *cartelisation* of the nitrogen industry was accelerated by a great crisis of over production from the late 1920s. Llopart shows in great detail, how the situation of overproduction in the 1930s led to complex negotiations, the setting up of production quotas and the parcelling out of the French market between the two main producing organisations, the ONIA and the *Confédération Française des Producteurs d'Azote* (CFPA). The negotiations between ONIA and CFPA involved considerable state intervention which, more generally, is a fundamental aspect to consider when reflecting upon the history of the fertiliser trade. Nitrogen, which could be used to manufacture both explosives and fertilisers, was indeed particularly singled out by political authorities as a strategic resource which could not be left to the private sector only. Llopart demonstrates how, although the government would have preferred to leave the development of this industry to the private sector, it eventually consented to create a state-owned plant in 1924 to produce and sell nitrogenous fertilisers, so as to be able to use these facilities to manufacture explosives in wartime, to regulate the fertiliser market in peacetime and prevent prices from being maintained artificially high by private actors. This state intervention led to a rather uncommon situation with the ONIA having a kind of hybrid legal status, with the state providing all the infrastructure and initial capital, but with the company then having to function independently without relying on the Treasury. This “unprecedented market configuration in France”, where a national industry had to compete with other private producers, quickly showed its limits with ONIA initially producing at rather uncompetitive prices, and thus being unable to fulfil its assigned aim of regulating and checking the influence of private cartels in setting prices.

5 Conclusion

While the historiography of the emergence of commercial fertilizers now covers a large set of issues, there are still many topics left to explore. This special issue intends to re-examine some of them by insisting on the interplay of actors as described in this introduction: political institutions, scientists, firms, farmers' unions, and ultimately farmers themselves who accepted or refused to use the wide set of promoted materials.

This special issue also indicates the necessity to re-think the distinction between organic, mineral or synthetic fertilisers, as their fertilizing powers did not depend on their mineral or organic origin, but on their chemical contents, identified around 1840 as crucial in the growth of plants.

Historians need to further disentangle and study the long process of acculturation that farmers experienced at the end of the 19th century and the beginning of the 20th century by which they re-learned agriculture (the famous N P K language), and better understand the complex dynamic and large set of actors which led to this crucial transformation. Focussing on the interplay between fertiliser manufacturers and farmers and political offices – the latter often acting as some sort of intermediary – will thus help understand the dynamics of industrialization effects on farming and also deepen our understanding of agricultural policy in the 20th century. Faced with an ever-growing population on a global and often national level, methods to increase agricultural production have been politically supported in numerous forms and to understand why which method(s) were chosen, it is necessary to study their historical origins. The articles in this volume provide important research towards that goal and will hopefully serve as starting points for future research.

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Bionotes

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