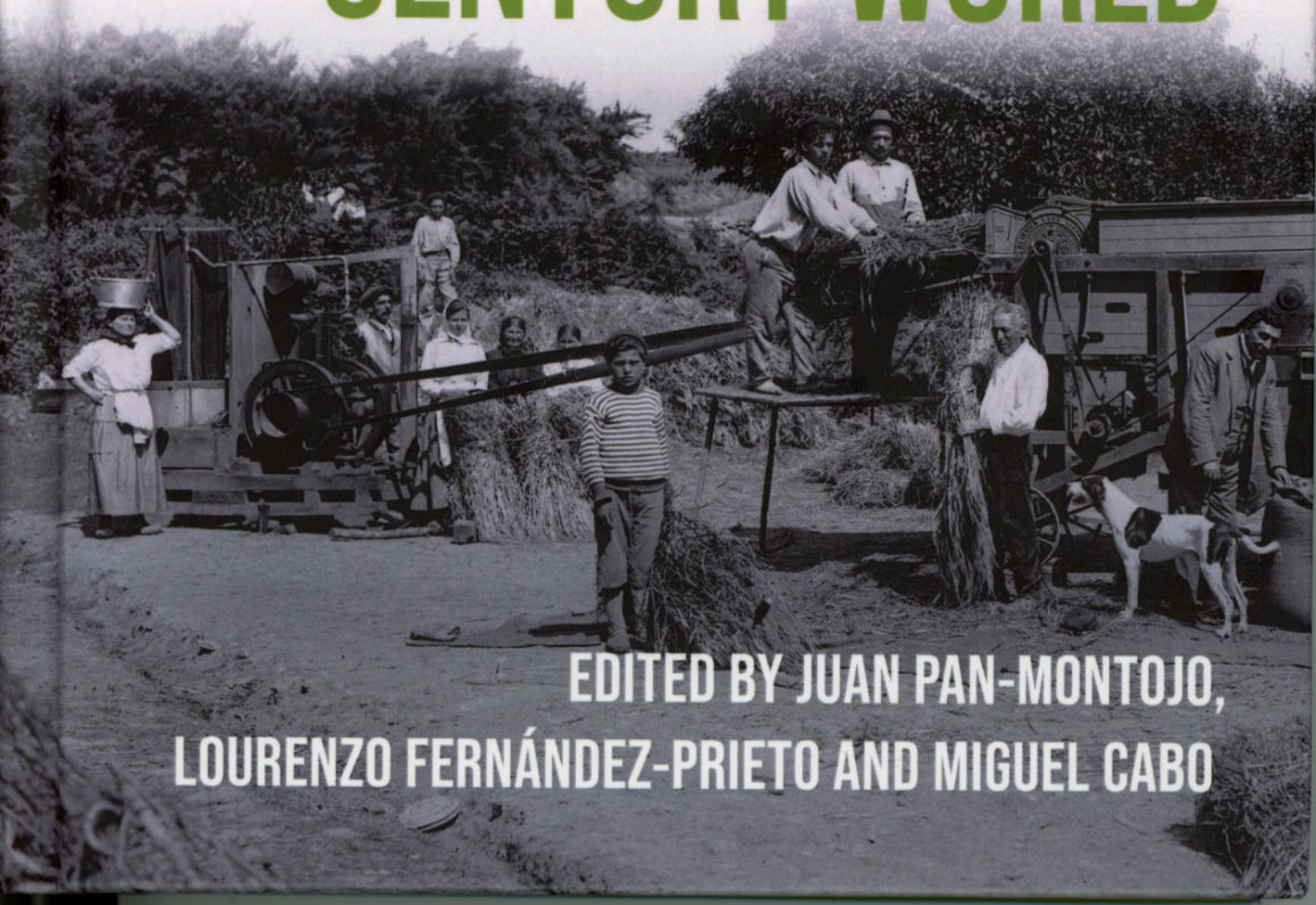
AGRICULTURAL MODERNISATION AND THE GREEN REVOLUTION IN THE TWENTIETH-CENTURY WORLD



EDITED BY JUAN PAN-MONTOJO, LOURENZO FERNÁNDEZ-PRIETO AND MIGUEL CABO

AGRICULTURAL MODERNISATION AND THE GREEN REVOLUTION IN THE TWENTIETH-CENTURY WORLD

Boydell Studies in Rural History

Series Editor

Professor Richard W. Hoyle

This series aims to provide a forum for the best and most influential work in agricultural and rural history, and on the cultural history of the countryside. While it is anchored in the rural history of Britain and Ireland, it also includes within its remit Europe and the colonial empires of European nations (both during and after colonisation). All approaches and methodologies are welcome, including the use of oral history.

Proposals or enquiries are welcomed. They may be sent directly to the editor or the publisher at the email addresses given below.

Richard.Hoyle@reading.ac.uk
editorial@boydellandbrewer.com

Previous titles in the series are listed at the back of the volume.

Agricultural Modernisation and the Green Revolution in the Twentieth-Century World

Edited by Juan Pan-Montojo,
Lourenzo Fernández-Prieto and Miguel Cabo

THE BOYDELL PRESS

First published 2026
The Boydell Press, Woodbridge

ISBN 978 1 83765 331 7

The Boydell Press is an imprint of Boydell & Brewer Ltd
and of Boydell & Brewer Inc.
website: www.boydellandbrewer.com

Our Authorised Representative for product safety in the EU is Easy Access System Europe – Mustamäe tee 50, 10621 Tallinn, Estonia, gpsr.requests@easproject.com

A CIP catalogue record for this book is available from the British Library

CONTENTS

2

Flow, stock and epistemic change: using biotic and consuming mineral resources in agricultural production

Juri Auderset and Peter Moser

In 1950, John M. Brewster, a philosopher who had worked for much of his career among agricultural economists at the USDA, published an article on the 'Machine Process in Agriculture and Industry'. He argued that 'the "Industrial Revolution" in agriculture' was 'merely a spectacular change in the implements of production whereas in industry it is a further revolution in the sequence (order) in which men use their implements'. Brewster obviously felt the need to elucidate this rather apodictic statement a little further and enlarged upon it in a footnote. Here he explained why motorised technologies had developed in different ways in the factories and in the fields since the invention of the steam engine in the late eighteenth century. To his eyes, these diverging developments stemmed from the 'contrasting nature of materials' used in agriculture and consumed in industrial manufacturing. 'Land' is a 'basic resource' in agricultural production. Farming deals, as Brewster put it, essentially with 'living things, fixed in the soil'. In industrial manufacturing, in contrast, the meaning of the land is usually reduced to being a 'building site' and the materials used are 'lifeless' and, therefore, much more 'mobile' and malleable to the requirements of the spatially fixed, continuously operated manufacturing system that has characterised the modern factory since its emergence in the late eighteenth and early nineteenth century. It was precisely the specific 'nature of materials' in industry that enabled an 'increased scale of production' and the 'concentration of operations required for their simultaneous performance', whereas agriculture remained tied to 'the seasonality of climate, biological cycles of living things, and the "spreadoutness" of the soil'. Therefore, Brewster argued, the 'machine process in agriculture and in industry' was subject

to different temporal and spatial logics of production stemming from the respective specific materiality used in the production process.[1]

It is as characteristic as is it is revealing for the transition period of the post-war decades that Brewster was eager to remind the readers of the *Journal of Farm Economics* of these differing material conditions of agricultural production and industrial manufacturing, but that he relegated these fundamental reflections to a footnote. This episode mirrors a broader shift in the history of agriculture as well as in its perception in the age of nineteenth- and twentieth-century industrial capitalism, a shift we call the transition from an *agrarian-industrial* knowledge society to an *industrial-agrarian* knowledge society.[2] The inversion of the two characterising adjectives is much more than a play on words. It indicates a fundamental epistemic shift in the perception and conception of agriculture closely related to the expansion of the material resource base of agricultural production. Whereas the epistemic reflection and practical consideration of the differences between the use of biotic and the consumption of fossil resources belonged to the main features of the agrarian-industrial knowledge society from the last third of the nineteenth century to the mid-twentieth century, this kind of reasoning on the 'contrasting nature of materials' in industry and agriculture was increasingly ignored (or, in Brewster's case, pushed to the footnotes) in the 1950s and 1960s. To integrate agriculture into the patterns of capitalist industrialisation on the verge of its 'great acceleration',[3] it had to be interpreted *as if it were* based on the same resources as industry. Had the representatives of the agrarian-industrial knowledge society struggled to find an adequate terminology to express the differentiation between the use of biotic and the consumption of mineral resources, many agricultural economists now began to identify this body of knowledge as an obstacle for a successful development of the agricultural sector in the post-war period. In Switzerland, for instance, the young agronomist Karl Steiner stated in 1955 that agricultural production had become 'an underdeveloped branch of the Swiss economy' because agricultural economists had for generations ignored 'the methodology and terminology of general business administration'. Instead of modelling the conceptual framework of agricultural economics on the idiosyncrasies

1 John M. Brewster, 'The Machine Process in Agriculture and Industry', *J. Farm Economics* 32 (1950), 69–70. On Brewster see John M. Brewster, *A Philosopher Among Economists*, J. Patrick Malden and David E. Brewster (eds) (Philadelphia, PA: J. T. Murphy, 1970).

2 Juri Auderset and Peter Moser, *Die Agrarfrage in der Industriegesellschaft: Wissenskulturen, Machtverhältnisse und natürliche Ressourcen in der agrarisch-industriellen Wissensgesellschaft (1850–1950)* (Vienna: Böhlau, 2018).

3 Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us* (London: Verso, 2017), 51.

of agricultural production, Steiner called for an active disregard of these specificities. Only by way of prescinding from agriculture's particularities could the theory of agricultural economics be aligned with 'the existing economic laws', and only when governed by the same allegedly universal principles of neoclassical economic theory could agriculture catch up with the pace of industrial development.[4]

This epistemic shift was tightly interwoven with the newly won access to the lithosphere and the growing use of mineral and fossil resources in agricultural production. The dream of turning farms into factories and of fitting agriculture completely into industrial capitalism reached back to the first half of the nineteenth century, but in the post-war years, this vision met with much more favourable material conditions for being turned into reality. In the 1940s, 1950s and 1960s, the long-term technological development of versatile, multifunctional, oil-fuelled tractors, equipped with power take-offs that transferred power directly to implements under tow, and endowed with rubber tyres that increased mobility between spatially dispersed fields and enabled a relatively flexible adhesion to changing soil conditions, was finally successful and marked a breakthrough in the process of motorisation of agricultural production.[5] Together with the growing use of chemical implements such as artificial fertilisers, pesticides, herbicides and insecticides that were also derived from minerals, agriculture began to participate to a significant degree in the consumption of mineral and fossil resources.[6] The intermeshing processes of motorisation and chemicalisation were not only crucial pre-conditions for the replacement of the innumerable draft animals that had powered the mechanisation of agricultural production since the nineteenth century, but they also made severe cutbacks in the

4 Karl Steiner, *Ein Fünf-Punkte-Plan zur Gesundung der schweizerischen Agrarwirtschaft* (Winterthur: Keller, 1959), 31 and 50. All translations from non-English sources are by the authors. On the influence of neoclassical economic theory see also Shane Hamilton, 'Managing the Farm: Bullshit in Theory and Practice', *Agricultural History* 98 (2024), 1–22.

5 Juri Auderset and Peter Moser, 'Mechanisation and Motorisation. Natural Resources, Knowledge, Politics and Technological Change in 19th and 20th Century Agriculture', in *Agriculture in Capitalist Europe, 1945–1960: From food shortages to food surpluses*, Carin Martiin, Juan Pan-Montojo and Paul Brassley (eds) (London: Routledge, 2016), 145–64. A detailed account of the technological developments of tractorisation is provided by Alan L. Olmstead and Paul W. Rhode, 'Reshaping the Landscape: The Impact and Diffusion of the Tractor in American Agriculture, 1910–1960', *J. Economic History* 61 (2001), 663–98. See also the contribution by Paul Brassley in this volume.

6 Nathalie Jas, *Au carrefour de la chimie et de l'agriculture: Les sciences agronomiques en France et en Allemagne, 1850–1914* (Paris: Édition des archives contemporaines, 2001); Adam M. Romero, *Economic Poisoning: Industrial Waste and the Chemicalization of American Agriculture* (Los Angeles, CA: University of California Press, 2021).

agricultural labour force possible. In conjunction with lithosphere-based inputs, the drastic decrease of men, women and working animals on farms enabled an impressive increase of the agricultural production for the markets in the post-war years.[7] What neoclassical economists conceptualised as a simple process of substituting labour through capital was in material reality an increasing consumption of non-renewable resources by an agriculture that simultaneously remained dependent on the use of living resources like animals, plants and soil.

From a historical perspective that emphasises the entanglements between the changing use of natural resources and the knowledge of agriculture in nineteenth- and twentieth-century industrial capitalism, the transition from an agrarian-industrial to an industrial-agrarian knowledge society is crucial since it marks the beginning of what we might call – following Foucault – a 'history of the present'.[8] In order to better grasp this shift in the interactions between the history of knowledge and the history of material resources in the post-war years, we must look a little further back into the twisting history of agriculture under the conditions of industrialisation in the nineteenth and twentieth centuries. In the following sections of this chapter, therefore, we will first sketch how agricultural production and industrial manufacturing came to rely on different resources in the context of the industrial revolution, which was more precisely a thermo-industrial revolution since it was the energy base and not the machines themselves that underwent revolutionary changes in that period. How did the rise of the steam-powered factory system in the middle of the nineteenth century unleash an indiscriminate belief that the agricultural practices of reproducing plants and animals could and should be modelled on the principles of industrial manufacturing? Second, we will discuss why this industrial paradigm ran up against the idiosyncrasies of agricultural production and explain why the experience of failure turned into an incentive to account for the peculiar features of agricultural reproduction from the 1870s onwards. In our understanding, these learning processes marked the beginning of the agrarian-industrial knowledge society and became one of its defining features until the 1940s. In this period, the appeal of the 'industrial ideal' remained intact,[9] yet the endeavours to modernise agriculture accounted for the specific logics of an agricultural mode of production embedded in

7 Giovanni Federico, 'Natura Non Fecit Saltus. The 1930s as the Discontinuity in the History of European Agriculture', in *War, Agriculture, and Food: Rural Europe from the 1930s to the 1950s*, Paul Brassley, Yves Segers and Leen Van Molle (eds) (London: Routledge, 2012), 15–32.

8 Michael S. Roth, 'Foucault's "History of the Present"', *History and Theory* 20 (1981), 32 –46.

9 Deborah Fitzgerald, *Every Farm a Factory: The Industrial Ideal in American Agriculture* (New Haven, CT: Yale University Press, 2003).

a great variety of ecological systems. In the third section our argument will come full circle and move back once again to the transition period of the post-war years. We will discuss the implications of this shift not only for the history of agriculture from the second half of the twentieth century to our present, but also for the historiographical narratives on agriculture that were – and often still are – deeply shaped by the ideological assumptions rooted in the post-war era.[10] In fact, as Miguel Cabo, Lourenzo Fernández Prieto and Juan Pan-Montojo remind us in the introduction to this volume, many of the dominating narratives about the development of post-war agriculture are enmeshed in the same conceptual schemes that contemporary advocates of a new type of industrialised and 'productivist' agriculture had proposed, continuing in their indifference towards the environmental and economic implications arising out of human activities that use biotic resources and those that consume mineral resources.

2.1 The rise of the industrial paradigm and its disenchantment

From the mid-nineteenth century, agriculture had increasingly become the 'other' in industrialising societies. This perception of agriculture's 'otherness' stemmed first and foremost from its differing resource base in comparison with industrial manufacturing.[11] Since the thermo-industrial revolution and the rise of the steam engine, the stationary, weather-independent system of industrial manufacturing was mainly based on the consumption of fossil and mineral resources stored in the lithosphere of the earth.[12] This technological breakthrough at the core of the thermo-industrial revolution not only made possible, for the first time in history, a decoupling of the production and reproduction processes, but it also enabled the transformation of a (temporary) abundance of coal (and later oil and uranium) into an affluence of kinetic energy. As Wrigley explained, this new 'resource capitalism' enabled industrialising societies to break free from the energy, raw material and food constraints of the previous 'organic economies' by way of consuming the '*stocks*' of mineral resources to complement the 'unvarying *flow* of energy arriving annually at the earth's surface':

10 Jonathan Harwood, 'Another Green Revolution? On the Perils of "Extracting Lessons" from History', *Development* 61 (2018), 43–53; Christophe Bonneuil, Léna Humbert and Margot Lyautey, 'Un renouveau de l'histoire contemporaine des mondes agricoles et des espaces ruraux', in *Histoire des modernisations agricoles au XXe siècle*, Margot Lyautey, Léna Humbert and Christophe Bonneuil (eds) (Rennes: Presses universitaires de Rennes, 2021), 7–20.

11 Nicholas Georgescu-Roegen, *Energy and Economic Myths: Institutional and Analytical Economic Essays* (New York: Pergamon 1976).

12 E. A. Wrigley, *Energy and the English Industrial Revolution* (Cambridge: Cambridge University Press, 2010).

> Within the context of an organically based economy, sustained and substantial growth sufficient to transform the standard of living was a utopian dream, whatever the prevailing economic system. To make the dream come true there had to be an escape to an economy not dependent on the annual product of the earth for all supplies of raw materials and energy. Such a regime involved a shift to mineral sources of supply and meant dependence upon a different kind of capital.[13]

Regardless of whether the 'dream' of an abundant disposability of mineral resources may always have had elements of a nightmare as well,[14] it doubtlessly installed a new economic regime that departed sharply from the 'organic economy' of earlier times. The 'resource capitalism' emanating from this access to the stores of mineral energy contained in the lithosphere and its consumption in the steam engine provided the necessary means for a continuous and linear, and thus accelerated, production that became the leading progressive vision in industrial societies in the nineteenth and twentieth centuries. Steam engines, a disciplined workforce, assembly lines, continuous manufacturing and scientific management with its 'time and motion studies' became the key symbols of this new industrial time- and space-regime.[15]

In the light of this industrial paradigm, the reproduction of plants and animals in agriculture that was heavily reliant on the use of biotic resources and the soil, and, by its very nature, bound to seasonally determined regeneration cycles, was increasingly seen to be in need of major transformation. The embeddedness of agricultural reproduction processes in the flows of the solar-biotic energy system and the bounds imposed on them by the limited surface area of the land encumbered a revolution of both labour and the production process, similar to the one observable in the factories.[16] As the German economist Werner Sombart observed at the beginning of the twentieth century, the use of fossil resources in industry enabled it:

> to break down the production process into its individual components and to order the operation in such a way that the individual sub-processes are carried out side by side or, this being no different,

13 E. A. Wrigley, *Poverty, Progress and Population* (Cambridge: Cambridge University Press, 2004), 76 and 85.

14 Andreas Malm, *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming* (London: Verso, 2016), 223–48.

15 Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the 20th Century* (New York: Monthly Review Press, 1974); Stephen Kern, *The Culture of Time and Space 1880–1914* (Cambridge, MA: Harvard University Press, 1983); Joshua B. Freeman, *Behemoth: A History of the Factory and the Making of the Modern World* (New York: W. W. Norton, 2018).

16 Susan A. Mann and James M. Dickinson, 'Obstacles to the Development of a Capitalist Agriculture', *J. Peasant Studies* 5 (1978), 466–81.

> at the same time. This happens, as we know, in every manufactory or factory, where at the same time the cotton bales are opened, the cotton is cleaned, roved, spun and the finished yarn is bleached and packed [...]. On the whole, the process is faster, and its overall duration is shortened [...]. In agriculture all of this is out of the question: both the total production process (from tilling to harvesting) is fixed in its duration, as well as its individual parts, which follow each other in a necessary, because natural, sequence. One cannot plough, sow and harvest at the same time (on the same crop).[17]

The resulting unevenness in the temporal and spatial regimes of agricultural production and industrial manufacturing was soon translated into the pervasive dichotomies and the conceptual teleologies that the nineteenth-century language of economic progress provided.[18] Pitting industrial manufacturing on the side of 'modernity' against agricultural production on the side of 'tradition', this mode of thought constructed farming as the 'other' in industrial societies by what the anthropologist Johannes Fabian calls 'temporal distancing' and a 'denial of coevalness'.[19] However, out of such conceptual dichotomies arose not only the assertion of difference, but also, and probably even more importantly, a new 'horizon of expectation'.[20] For agriculture to march in sync with industrial progress, it had to become industry-like. Integrating agriculture into the realm of an industrial society thus required both its subordination under the hegemonic conceptions of industrial progress and its involvement in the use of the same resource base that had shaped manufacturing industry since the times of the thermo-industrial revolution.[21]

2.2 From an agrarian-industrial knowledge society ...

By the 1870s, however, a growing number of farmers and agricultural observers concluded that the idiosyncrasies of agricultural production must also be taken into account, because many of the industrially

17 Werner Sombart, *Die deutsche Volkswirtschaft im neunzehnten Jahrhundert und im Anfang des 20. Jahrhunderts*, 5th edn (Berlin: Georg Bondi, 1921), 344.

18 Peter Wagner, 'Autonomy in History: Teleology in Nineteenth-Century European Social and Political Thought', in *Historical Teleologies in the Modern World*, Henning Trüper, Dipesh Chakrabarty and Sanjay Subrahmanyam (eds) (London: Bloomsbury, 2015), 323–38.

19 Johannes Fabian, *Time and the Other: How Anthropology Makes its Object* (New York: Columbia University Press, 2002), 30–1.

20 Reinhart Koselleck, *Futures Past: On the Semantics of Historical Time* (New York: Columbia University Press, 2004), 255–75.

21 Peter Moser and Tony Varley, 'The State and Agricultural Modernisation in the Nineteenth and Twentieth Centuries in Europe', in *Integration through Subordination: The Politics of Agricultural Modernisation in Industrial Europe*, Peter Moser and Tony Varley (eds) (Turnhout: Brepols, 2013), 13–39.

inspired schemes for modernising farming ran up against the specific logics of agricultural production. The manifold attempts to introduce the steam engine in agriculture, for instance, were, if not a downright failure, at least only a very partial success. To keep the heavy steam engine going in the fields required nearly as many horses and oxen for transporting coal and water as had been made obsolete in the process of ploughing. The distribution and successful application of steam engines in agriculture were limited to activities in the farmyard like threshing. In other words, the power of the steam engine was not used to facilitate the production process itself, but, just as in industry, for the stationary transformation of a product: in this case, cereals into grain and straw.[22] Thus, the use of the steam engine in agriculture proved to be advantageous only for stationary work. It failed to revolutionise agricultural fieldwork that required a much more mobile, adaptable and flexible source of power. Even Karl Kautsky, who was otherwise convinced that agriculture would henceforward develop in the wake of industrial development, acknowledged in his 1899 classic *The Agrarian Question*, that the introduction of motorised machinery in agriculture faced more hurdles than the motorisation of manufacturing in industry because 'the industrial workplace, the factory, is an artificial creation, adapted to the requirements of the machine' whereas in agriculture 'most machines have to work in and adapt to natural surroundings'.[23]

It was the challenge of adapting to heterogeneous, weather-dependent and rapidly changing natural surroundings that was not met by agricultural machine engineering for a long time. Consequently, neither the steam engine nor early combustion motors replaced draft animals in agriculture to any significant degree. Quite the contrary: at the same time as contemporaries heralded the 'age of steam' and witnessed the rise of a 'machine age', working animals experienced their apotheosis on the farms (and, for a few decades, in the transport systems of cities).[24] Whereas the technological exploitation of fossil resources gradually displaced working animals from factory production and long-distance transportation, they continued to perform a wide variety of tasks in other areas of social life, especially in rural areas. Their numbers on farms rose significantly until the 1930s, and in some regions until the mid-twentieth century. Indeed,

22 David Goodman, Bernardo Sorj and John Wilkinson, *From Farming to Biotechnology: A Theory of Agro-Industrial Development* (Oxford: Basil Blackwell, 1987), 21.

23 Karl Kautsky, *The Agrarian Question: In Two Volumes* (London: Pluto Press edn, 1988), 32.

24 Ann Norton Greene, *Horses at Work: Harnessing Power in Industrial America* (Cambridge: Cambridge University Press, 2008); Peter Moser and Andreas Wigger, *Working Animals: Hidden Modernisers Made Visible*. ARH/ERHFA Video Essay No. 1, Bern, 2022. https://ruralfilms.eu/ruralfilms/video-essays/working-animals (accessed 22 September 2023).

the mechanisation of agriculture in the nineteenth and in the first half of the twentieth century depended much more on the muscular power of animals (and human beings) than on the consumption of coal and petrol.[25] As one keen observer noted in an American newspaper in 1872: 'Our talk has been for so many years of the railroad and steamboat and telegraph, as the great "agents of progress", that we have come almost totally to overlook the fact that our dependence on the horse has grown almost *pari passu* with our dependence on steam'.[26]

Such reasoning was emblematic for the rise of the agrarian-industrial knowledge society that shaped the relations between agriculture and industrial culture from the 1870s to the 1940s. In this period an ensemble of actors, institutions, discourses and practices began to address agrarian questions not solely from a perspective that emphasised farming's alleged deficiencies in comparison to industrial production but tried to accommodate agriculture's specificities with the demands of the industrial age. From this constellation emerged a variety of contested and hybrid forms of knowledge that were highly significant in shaping agriculture's transformation in industrial-capitalist societies. Thus, the knowledge regime emanating in this period was characterised by myriad endeavours to accommodate agricultural production to the expectations of industrial modernity, while simultaneously respecting agriculture's specificities, especially its anchoring in the biosphere. This became the core epistemic feature of the agrarian-industrial knowledge societies on both sides of the Atlantic.[27]

Again, the topic of mechanisation is instructive in this regard as disenchantment with attempts to use steam and combustion engines in agricultural production by no means led to an abandonment of efforts to motorise agriculture. On the contrary, machine engineers and farmers were busy developing agricultural machinery that was suitable for the varying and heterogeneous conditions of agriculture from the last quarter of the nineteenth century onwards.[28] At the very same time, however, the increasing importance of working animals intensified the practical and

25 Juri Auderset and Hans-Ulrich Schiedt, 'Arbeitstiere: Aspekte animalischer Traktion in der Moderne', *Traverse* 2 (2021), 27–42.

26 'The Position of the Horse in Modern Society', in *The Nation*, 31 October 1872.

27 Justus Hillebrand, 'To Know the Land with Hands and Minds: Negotiating Agricultural Knowledge in Late-Nineteenth-Century New England and Westphalia' (PhD diss., University of Maine 2021); Juri Auderset and Peter Moser, 'Exploring Agriculture in the Age of Industrial Capitalism: Swiss Farmers and Agronomists in North America and the Transnational Entanglements of Agricultural Knowledge', *Agricultural History* 96 (2022), 91–127.

28 Deborah Fitzgerald, 'Technology and Agriculture in Twentieth-Century America', in *A Companion to American Technology*, Carroll Pursell (ed.) (Malden: Blackwell, 2008), 69–82.

scientific preoccupation with these 'living motors'. While the endeavours to develop suitable motorised technologies struggled with the diversities of soil, weather and topographies, farmers, agronomists, veterinary surgeons and animal breeders began to conceptualise animals not only as producers of milk and meat for human and animal consumption but, simultaneously, also as 'prime movers' in agricultural production. The body and mind of the multifunctional draft animals became an 'epistemic object', worthy of elaborate and sometimes expensive observations, studies and scientific experimentations.[29] Breeders began to collect data concerning the ancestry of the animals, kept records on their performance, applied information processing procedures, statistics and theories of inheritance for selective breeding and thus increased the average weight, height and pulling power of draft animals along with simultaneously increasing their milk and meat production. Veterinary surgeons and agronomists analysed the physiology, anatomy and motion of their bodies, and tried to improve their versatility and the relationship of energy incorporated in feed and exhausted by work. The farming population sharpened its long-established hermeneutic culture of observation of the behaviour of the animals, often crediting them with qualities reserved in industrial circles for human beings, such as character, memory and capacities to learn. In short, the farm became a crucial site of observation and an important intersection of scientific and tacit knowledge production regarding the animal as an 'intelligent' and variable energy source for increasing and facilitating agricultural production. Working animals were by no means simply a source of power to be replaced by steam engines, locomotives, electric streetcars, automobiles, tractors and combine harvesters. They became polyvalent and versatile agricultural 'working companions'[30] and, as such, factors of agricultural modernisation itself. Animal-powered agriculture 'was a great modernising force', as Edgerton reminds us.[31]

In agricultural production from the 1870s until the middle of the twentieth century, working animals, steam engines, combustion and electric motors were thus 'technologies in tension'.[32] The history of working animals and motors in this period is less a history geared towards

29 Juri Auderset and Hans-Ulrich Schiedt, 'Die Vermessung des animalischen Motors. Körpergrössen, Zugkraft und Metabolismus der Arbeitstiere, 1800–1950', *Body Politics* 10 (2022), 57–87.

30 Peter Moser, 'Working Animals – A Historical Approach', in *Draft Animals in the Past, Present and Future*, Claus Kropp and Lena Zoll (eds) (Heidelberg: Propylaeum, 2022), 129–36.

31 David Edgerton, *The Shock of the Old: Technology and Global History Since 1900* (London: Profile, 2019), 34.

32 Gijs Mom and David A. Kirsch, 'Technologies in Tension: Horses, Electric Trucks, and the Motorization of American Cities', *Technology and Culture* 42 (2001), 489–518.

replacement than one of the plural uses of differently available and differently reliable sources of power. It is thus a history of simultaneity, interaction and complementarity of human, animal and motor energy. It is revealing for the character of the agrarian-industrial knowledge regime that the discourse on the farm power question was by no means structured by an antagonistic pattern that pitted the draft animals against the motor or by one-dimensional future-orientated narratives that heralded the overcoming of the animal's muscular force by fossil fuels. Rather, animals and motors were conceptualised as complementary tools. Farmers and agronomists distinguished between operations more suitable for motorised machinery and others that required the brains and bodies of working animals or humans. In this sense, farmers were – to use Claude Lévi-Strauss' concept – in many ways 'bricoleurs' who pragmatically combined different forms of energy provision because they were aware of the heterogeneous and changing conditions of their work, which in turn required versatile and adaptive strategies.[33] This intellectual culture of distinguishing the properties of different kinds of natural resources and to value a certain source of energy in relation to the tasks to be completed and to the specific conditions under which work had to be done is one of the leitmotifs that permeates the discourse on mechanisation and motorisation in the period of the agrarian-industrial knowledge society.

2.3 … to an industrial-agrarian knowledge society

In the post-war years, however, the relations between agricultural production and the hegemony of industrial culture shifted again, as it had in the period before the 1870s, towards a one-sided orientation on the industrial paradigm. Reflections on the specific material logics of biotic resources, which were crucial in the era of the agrarian-industrial knowledge society, rapidly vanished from agronomic discourses, especially from the textbooks of agricultural economics, giving way to a far-reaching embrace of what came to be called 'industrial' agriculture as part of a general perception of modernity. The voices that insisted on continuing to differentiate between the implications of the use of living and the consumption of mineral resources were pushed to the margins or, in agronomic literature, to the footnotes, as becomes clear from Brewster's article quoted above. Thus, the *agrarian-industrial* knowledge society mutated into an *industrial-agrarian* knowledge society. In sharp contrast to the earlier knowledge regime, the epistemic consensus now rested on the assumption that there were no significant differences in the resource bases of industry and agriculture. In the course of this epistemic transition,

33 Claude Lévi-Strauss, *La pensée sauvage* (Paris: Plon, 1962), 26.

a faith in scientific progress and technological advancement along the lines of industrial manufacturing spread through industrialised societies in Western and Eastern Europe alike.[34] Under the specific geopolitical conditions of the Cold War, moreover, this conception of a universally valid modernisation as the cure to all possible ills soon translated into suggestions for the agricultural and rural development of the so-called Global South.[35] The 'belief – in the face of contrary evidence – in the redemptive power of science and economic growth' permeated what came to be called the Green Revolution,[36] giving rise to a world-wide version of agricultural progress that James C. Scott labelled 'high modernist agriculture'.[37]

To be sure, this vision of agricultural change originated in the middle of the nineteenth century when books with titles like *The … peasant as he should be, and is not, and how he is and should not be* were first published.[38] This wishful thinking has a long history and has fuelled attempts to integrate agriculture into industrial capitalism for decades, but – as we have seen – in the age of the agrarian-industrial knowledge society from the 1870s to the 1950s it resulted in a complex process of accommodation as the farming population and agronomists reflected on the different ecological implications of the use of biotic and the consumption of mineral resources. In the 1950s and 1960s, however, the unbroken desire to transform farms into industrial enterprises – or peasants into farmers – regained traction. Unlike in the middle of the nineteenth century, it now fell on more fertile ground because broadened access to fossil resources made it possible to replace working animals with motor-driven machines and the relatively cheap, seemingly unlimited availability of fertilisers

34 Arnd Bauerkämper, 'The Industrialization of Agriculture and its Consequences for the Natural Environment: An Inter-German Comparative Perspective', *Historical Social Research* 29 (2004), 124-49.

35 See the contributions in *Staging Growth: Modernization, Development, and the Global Cold War*, David C. Engerman, Nils Gilma and Mark H. Haefele (eds) (Amherst, MA: University of Massachusetts Press, 2003); Corinna R. Unger, 'Developing Rural Regions: Europe in the World', in *Living With the Land: Rural and Agricultural Actors in Twentieth Century Europe*, Liesbeth van de Grift, Dietmar Müller and Corinna R. Unger (eds) (Berlin: de Gruyter, 2022), 61–82.

36 Nick Cullather, 'Miracles of Modernization: The Green Revolution and the Apotheosis of Technology', *Diplomatic History* 28 (2004), 227–54, at 230. See also the contributions by Jonathan Harwood, Luis E. Blach, Madhumita Saha, Michele Sollai, as well as by Wilson Picado-Umaña and José A. Fernández Molina in this volume.

37 James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998), 262.

38 [Zacharias Gysel], *Der Schaffhauser Bauer, wie er sein sollte, und wie er nicht ist, wie er ist, und wie er nicht sein sollte* (Schaffhausen: Brodtmann, 1854).

and pesticides made a level of uniformity and standardisation in farming feasible in a way that was without historical precedent.[39]

But this shift was not only based on the new access to the lithosphere (and accompanied by far-reaching ecological and social consequences): it also stemmed from fundamentally changing epistemic frameworks. As the farmer and author Wendell Berry observed in 1984, 'farmers and consumers alike dance to a tune called by the industrial economy'. The capabilities of farmers as producers of knowledge, based on 'skill, intelligence, experience and imagination' and sensitive to 'many possible solutions' that had to be applied 'with skill in the right place at the right time' were increasingly pushed to the margins as an 'industrial version of agriculture' became hegemonic. Under the conditions of this industrial way of seeing, Berry writes, 'farming brings the farmer annually, over and over again, to the same series of problems, to each one of which there is always the same generalized solution, and, therefore, that industry's solution can be simply and safely substituted for his solution'.[40]

From such a point of view, the farmer's knowledge, derived from the labour process working with living resources, was no longer perceived as an empowering intellectual force, but rather as an obstacle to the shaping of agriculture according to industrial models. Indeed, the post-war years saw a thrust towards conceiving the farm as a site of applied science and neoclassical business economics, reinforcing the belief that the idiosyncrasies of agricultural production could and should be overcome. This in turn opened the farm gates to the intrusion of 'expert' knowledge produced and disseminated by a growing number of agronomists, technicians, veterinary surgeons, inseminators, advisors, accountants and salesmen. But the farm gates opened not only for these experts and the knowledge needed to exploit the new production possibilities, but also for capital. One of the most significant changes in agricultural production after the Second World War was the displacement of production activities from the actual farm to upstream and downstream agribusinesses, a process that the Swiss agronomist Oskar Howald called

39 Christian Pfister, 'The "1950s Syndrome" and the Transition from a Slow-Going to a Rapid Loss of Global Sustainability', in *The Turning Points of Environmental History* (ed.) Frank Uekötter (Pittsburgh, PA: Pittsburgh University Press, 2010), 90–118; Peter Moser, 'Zugriff auf die Lithosphäre: Gestaltungspotenziale unterschiedlicher Energiegrundlagen in der agrarisch-industriellen Wissensgesellschaft', *Traverse* 3 (2013), 37–48; Céline Pessis, Sezin Topçu and Christophe Bonneuil (eds), *Une autre histoire des 'Trente Glorieuses': Modernisation, contestations et pollutions dans la France d'après-guerre* (Paris: La Découverte, 2013).

40 Wendell Berry, 'Whose Head Is the Farmer Using? Whose Head is Using the Farmer?', in *Meeting the Expectations of the Land: Essays in Sustainable Agriculture and Stewardship*, Wes Jackson, Wendell Berry and Bruce Colman (eds) (San Francisco, CA: North Point Press 1984), 23 and 25.

the 'dis-integration' of the farm.[41] Instead of reproducing a substantial part of the means of production on the farm, farmers were now increasingly forced to purchase them as commodities supplied by private enterprises. This not only altered the relative positions of capital and labour in agriculture, but also necessitated the active intervention of the state in backing the farmer's need for capital since agricultural re-production was (still) not attractive enough for private capitalists to invest in.[42] In sum, agriculture in the 1950s and 1960s witnessed parallel to its dramatically increasing dependence on fossil fuels and far-reaching social and economic disruptions, a significant epistemic shift away from an intellectual occupation with the temporal and spatial logics of living resources towards a 'voice of decontextualized rationality'[43] that saw in agricultural practice little more than the management of an 'industrial unit' detached from its embeddedness in specific ecological, social and cultural contexts.

These changes were part of a broader shift towards a 'dematerialization of the economic discipline'.[44] Peter Rieder, professor of agricultural economics at the Swiss Technical University (ETH) in Zürich wrote in hindsight about the 1960s: 'We all learned neoclassical economics and mathematics for economists' and became 'model builders'.[45] The abstracting logic of constructing models serving the allegedly 'rational' decision-making of farmers pushed considerations of the material bases of agricultural production to the margins. Plants, animals or the soil and their differing potentials and limitations disappeared from mainstream economic theory and from agricultural economics alike.[46] Agricultural

41 Oskar Howald, 'Betrachtungen zur Abgrenzung des Geltungsbereiches des Landwirtschaftsgesetzes von 1951', *Agrarpolitische Revue* 20 (1963/4), 460–1. On this process see also Jack R. Kloppenburg Jr, *First the Seed: The Political Economy of Plant Biotechnology, 1492–2000* (Madison, WI: University of Wisconsin Press, 2004), 31.

42 Søren Mau, *Stummer Zwang: Eine marxistische Analyse der ökonomischen Macht im Kapitalismus* (Berlin: Dietz, 2021), 263.

43 Jack R. Kloppenburg Jr, 'Social Theory and the De/Reconstruction of Agricultural Science. Local Knowledge for an Alternative Agriculture', in *Geographic Thought: A Praxis Perspective,* George Henderson and Marvin Waterstone (eds) (London: Routledge, 2009), 248.

44 Jean-Baptiste Fressoz and Christophe Bonneuil, 'Growth unlimited: The idea of infinite growth from fossil capitalism to green capitalism', in *History of the Future of Economic Growth: Historical Roots of Current Debates in Sustainable Degrowth,* Iris Borowy and Matthias Schmelzer (eds) (London: Routledge, 2017), 57.

45 Peter Rieder, 'Bauern und Dörfer im Berggebiet – Realität, Theorien und Modelle', *Yearbook of Socioeconomics in Agriculture* (2012), 11–30.

46 Juri Auderset and Peter Moser, 'Permanenz des Unbehagens: Epistemischer Wandel und agrarpolitische Re-Regulierungen im Zeitalter des Neoliberalismus', in *Zwang zur Freiheit: Krise und Neoliberalismus in der Schweiz,*

economy too was now conceptualised as a totality of exclusively monetary relations linking production, distribution and consumption. Re-conceived as such, economic activities were severed from their embeddedness in material resources and, therefore, from any material limits to economic growth. In this dematerialised conception of the economy, the hegemony of the 'growth paradigm' set in.[47] As Timothy Mitchell puts it:

> Older ways of thinking about wealth were based upon physical processes that suggested limits to growth: the expansion of cities and factories, the colonial enlargement of territory, the accumulation of gold reserves, the growth of population and absorption of migrants, the exploitation of new mineral reserves, increasing volumes of trade in commodities. All these were spatial and material processes that had physical limits [...] [From the 1930s on], the leading contributions to the academic formulation of the economy [...] paid no attention to the depletion of energy. The economics of growth of the 1950s and 1960s could conceive of long-run growth as something unrestrained by the availability of energy.[48]

This scientific 'generation of ignorance'[49] towards the material basis of economic processes in general and agricultural processes in particular had far-reaching implications, not only for environmental degradation, but also for historical narratives of agricultural change in the post-war era. The rise of what Nicholas Georgescu-Roegen termed 'growthmania'[50] coincided with the 'third agricultural revolution', the most critical feature of which was the newly gained access to the vast but finite fuel reserves of the lithosphere. In other words, since the 1950s food production, processing and transport are largely, albeit never fully, based on the consumption of the same fossil fuel reserves that the manufacturing industry has relied on since the early days of the thermo-industrial revolution. The growing use of fossil resources to fuel motorised machinery, combined with the cultivation of high-yielding varieties that depended on massive inputs of fertilisers and pesticides, not only led to a sharp drop in demand for human and animal labour on farms and unprecedented increases in production for the markets, but also to a range of environmental degradations such

---

Regula Ludi, Matthias Ruoss and Leena Schmitter (eds) (Zurich: Chronos, 2018), 37–60.

47 Matthias Schmelzer, 'The Growth Paradigm: History, Hegemony, and the Contested Making of Economic Growthmanship', *Ecological Economics* 118 (2015), 262–71.

48 Timothy Mitchell, 'Carbon Democracy', *Economy and Society* 38 (2009), 417–18.

49 Jan Douwe van der Ploeg, *The New Peasantries: Struggles for Autonomy and Sustainability in an Era of Empire and Globalization* (London: Earthscan, 2009), 17.

50 Nicholas Georgescu-Roegen, 'Inequality, Limits and Growth from a Bioeconomic Viewpoint', *Review of Social Economy* 35 (1977), 372.

as loss of biodiversity, the nitrification of groundwater, as well as soil erosion and soil compression.[51] However, the environmental consequences of these agricultural modernisation programmes were in general either ignored, exculpated in the name of economic growth, or turned into collateral damages that the imagined scientific and technological progress would take care of sometime in the future.

The post-war knowledge regime had thus unburdened itself of the need to think about the idiosyncrasies of different natural resources and their respective logics. Within this epistemic framework, it became increasingly impossible to think of the modernisation of agriculture in any way other than in terms of its industrialisation. In practice, however, this continually created ecological fault-lines and social dislocations and continues to do so today. They remind us that an agriculture based on the sustainable use of biotic resources inevitably comes into conflict at the material level with industrial capitalist expectations of growth and efficiency fed by a mode of production based on the consumption of fossil and mineral resources. These tensions may be temporarily obscured by the ideology of dominant development narratives and short-term technological fixes, but they keep haunting us in the agricultural realities of our present. Looking back at the agricultural revolutions of past centuries, we might recall Walter Benjamin's words: 'Marx says that revolutions are the locomotive of world history. But perhaps it is quite otherwise. Perhaps revolutions are an attempt by the passengers of the train – namely the human race – to activate the emergency brake'.[52]

51 Frank Uekötter, *Die Wahrheit ist auf dem Feld: Eine Wissensgeschichte der deutschen Landwirtschaft* (Göttingen: Vandenhoeck & Ruprecht, 2010).

52 Walter Benjamin, quoted from Michael Löwy, *Fire Alarm: Reading Walter Benjamin's 'On the Concept of History'*, (London: Verso, 2005), 66–7.