8 Mechanisation and motorisation

Natural resources, knowledge, politics and technology in 19th- and 20th-century agriculture

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Introduction

When August Strindberg travelled around rural France in the 1880s in order to understand the development of French agriculture facing the rise of industrialisation and a first wave of globalisation, he was impressed by the fundamental changes in the landscape of the heavily industrialised Normandy. In industrial production, Strindberg observed, the steam engines literally 'fed themselves' into the earth's interior in order to access the longed for coal stocks.[1] In contrast to the vertical digging movements of the steam engine into the lithosphere, the 'organic motors' of draught animals used in agriculture moved horizontally, nourished by plants grown within the biosphere.[2]

Strindberg's observation is more than a vivid blending of topographical, metabolic and technological metaphors. It sketches an important analytical perspective on the resource basis of technological change and reminds us of the importance of distinguishing between mechanisation and motorisation, two terms often confusedly used when it comes to the analysis of 19th- and 20-century agriculture.[3]

Machines in agriculture were up to the middle of the 20th century basically powered by a rising number of draught animals (horses, cattle, dogs) whose upkeep was contingent upon plants and animals continuously reproduced in the process of production. As long as animal (and human) power remained the principal source of power for machines in agriculture, it was simply impossible to create the same growth rates in agriculture as in industrial production, whose rising volume and productivity in the 19th century can mainly be attributed to the steam engine, entirely depending on the consumption of mineral resources from the lithosphere.[4] The manifold attempts to introduce the steam engine in agriculture were, if not a downright failure, at least only a very partial success.[5] Generally speaking, its distribution and successful application was limited to activities in the farmyard like threshing, mostly activities which occurred due to the seasonality and cyclicity of all agricultural work, but not continuously. While the steam engine was the perfect solution for a spatially fixed, continuously operated production, it was rather ill suited for the improvement of the decentralised, cyclical, seasonally bound and weather-dependent production processes in agriculture. As Eduard David, the German socialist thinker, shrewdly observed in his book *Socialism and Agriculture*, the steam engine did *not* have the same revolutionary impact in agriculture as it had in industry, where it was possible to organise production 'in a continuing chain of mechanic operations'. In contrast, the temporal and spatial structures of the biotic resources used in agriculture rendered it impossible to convert temporally discontinuous and spatially dispersed patterns of (re)production into temporally synchronic and continuous and spatially concentrated, modularised sequences of production.[6]

While the thermo-industrial revolution enabled a continuous process of production in the industrial sector, it strengthened the cyclical production rhythms in agriculture.[7] Here, the industrially produced machines and equipment suitable for improving the production demanded not steam engines but draught animals such as horses, oxen, cattle and even dogs. They were all a much more suitable source of power in agricultural production than the steam engine. For almost a century, in agriculture they were conceptualised and installed as organic motors and produced comparable, but significantly different, results from the distribution of the steam engine in industry. Since they were biotic resources themselves, they shared many similarities with the living matter they were used to improve. Draught animals were adaptive and interacted with men who tried to improve and model them actively for their purposes through breeding, feeding and husbandry methods. Hence, mechanisation in agriculture went along with the creation, increase and improvement of draught animals. Farmers, farm labourers and farm women developed a great variety of methods for educating and training animals in their youth to work, often in co-operation with older, already 'learned' animals such as the mare in the case of foals.

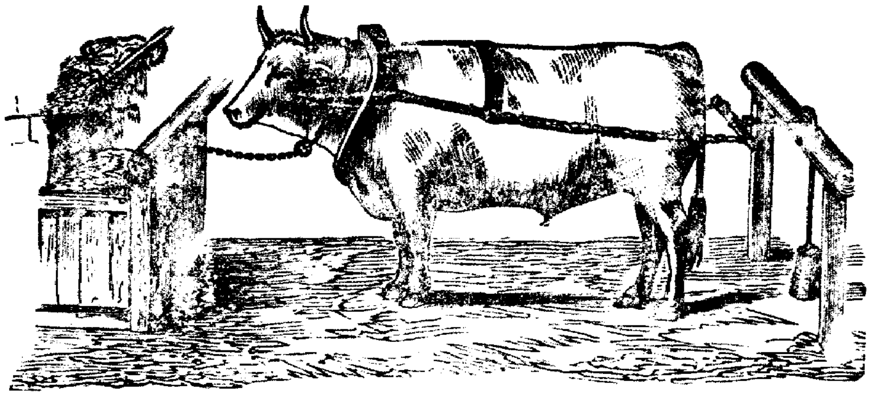

Figure 8.1 A widely used draught-training method for horses and cattle in the 19th century

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Figure 8.2 Educating instead of breaking horses: men and animal in a co-operative educational enterprise for socialising foals into their future role as draught animals

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The number of draught animals in rural areas rose significantly in the second half of the 19th century, whereas they gradually disappeared in industry and the transport systems. Here, they were first replaced by steam and then by combustion engines.[8]

The simultaneousness of a continuous throughput of energy in industry and discontinuous rhythms of energy input, throughput and output in agriculture puzzled contemporaries as early as in the middle of the 19th century. While scientists and adherents of the industrial society advocated an outright industrialisation of the agricultural sector, the biotic resources resisted certain forms of this particular form of modernisation and, therefore, created tensions and frictions between the emerging industrial societies and their agricultural sectors.[9] Besides establishing endless ideological debates[10] they also turned out to be a productive force of intellectual differentiation and knowledge production that eventually generated an agrarian–industrial knowledge society whose actors were trying to meet the requirements of the agricultural reproduction, including seasonally bound use of biotic resources, with those of the lithosphere based industrial society.[11]

When the 'motor dreams', so popular in the middle of the 19th century, were shattered again and again when applied in agricultural practice, astute observers became convinced that engines fit for agriculture had to blend the diversity of skills so characteristic of the draught animal with the steadiness, speed and precision of the combustion engine.[12] The comparison of the combustion motor and the organic motor of the draught animal became the crucial interpretative pattern in the development of agricultural technologies.

It was not until the 1940/50s, however, that a complex interplay between the significant enlargement of energy resources, epistemic changes, technological innovations, political interventions and sociocultural dispositions led to the breakthrough of the combustion engine in agriculture. The long dreamed of, versatile, multifunctional, oil-fuelled tractor, 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 and terrains, was finally developed in a close co-operation between farmers, engineers and agronomists. Only the appearance of these versatile tractors enabled agriculture to participate in a significant way in the consumption of mineral resources – a precondition for the replacement of the now innumerable draught animals and the impressive growth of agricultural production and productivity in the post-war years.[13]

In the following sections we will explore the processes of mechanisation and motorisation from the middle of the 19th century to the 1960s by emphasizing the different potentials and limitations of mineral and biotic resources. It was basically this different resource basis in industry and agriculture which led to such notable differences between the patterns of mechanisation and motorisation in industry and agriculture and not, as historians have tended to argue, the assumed conservative character of the peasants, their sentimental and irrational veneration for the horse, their apparent dislike for technological innovations and their quasi-Luddite tendencies against progress.[14] A close reading of the sources suggests that the farming population by and large made quick, efficient and creative use of new technologies, if they were actually capable of improving the process of reproduction.[15] Farmers themselves were anxious to improve existing technologies or develop new ones. Since technological choices are always accompanied by contingencies, uncertainties and unintended consequences, farmers carefully reflected on the practical use of new inventions in order to minimise the high technology-induced risks. An implementation of new technology in agricultural practice, therefore, depended on many more aspects than the availability and transfer capacities of technology from the factory or the workshop to the farm.

To take the different resource basis in agriculture and industry seriously opens up, in a combination with an historic-epistemic approach, a new perspective for the history of mechanisation and motorisation that avoids the trap of technological or energetic determinism.[16] Our approach, therefore, emphasises the interactive relationships between the specific material conditions of energy use, the social force of historic epistemic cultures in shaping reality and the path dependencies and dynamics of technological change.[17] From this perspective, the mechanisation and motorisation of agriculture can no longer be narrated as the result of a smooth – albeit, compared to the industrial sector, late – 'victory of change and progress over traditionalism and apathy'.[18]

In order to underpin this alternative narrative of technological change in 19th- and 20th-century agriculture, we will first trace the attempts to introduce the steam engine in agriculture and then discuss how this failure shifted intellectual attention to the observation, analysis and improvement of draught animals that were increasingly conceived as organic or animal motors. Second,

we will argue that the semantic spill-over of this metaphor not only had illustrative and heuristic effects, but also constitutive and epistemic ones.[19] From the 1870/80s onwards, self-propelled, motor-driven agricultural machinery was increasingly shaped after the specific capabilities of draught animals. Therefore, the tacit as well as the newly gained scientific knowledge of the animal body, its specific emotional, intellectual and physical capacities, its physiology, agility and multifunctionality became something like a blueprint for the invention of motor-powered agricultural machines. Third, we will focus on the causes of the gradually successful motorisation of agricultural production in the 1940/50s and the profound impacts it had far beyond the agricultural sector.

The failure of the steam engine and the rise of the draught animal

The steam engine was, according to Joel Mokyr, 'one of the most radical inventions ever made'.[20] If we take into account that the thermo-industrial revolution for the first time in history enabled actors to decouple the processes of production and reproduction in the industrial sector, it was probably even *the* most important invention. The disconnection of the production from the necessity to reproduce the consumed resources nurtured the vision that eternal growth was a concept that could be applied to the economic sphere. The steam engine, therefore, not only transformed a (temporary) abundance of coal into an affluence of kinetic energy, it also transcended the knowledge of the temporal and voluminous limits of an 'organic economy' and introduced the notion of an ever growing economy.[21] Not surprisingly, the steam engine became *the* central iconic symbol of the 'culture of technology' in the 19th century.[22] In a characteristic vison of the zeal for technological progress, the machine engineer M.A. Alderson argued in 1834 that the advantages of the steam engine lay in its capacity to overcome the physiological limits and the cyclical and land-bound patterns of energy use inherent in an animal powered economy:

> Animals require long and frequent periods of relaxation from fatigue, and any great accumulation of their power is not obtained without great expense and inconvenience … To relieve us from all this difficulties, the last century has given us the steam-engine for a resource, the power of which may be increased to infinitude: it requires but little room – it may be erected in all places, and its mighty services are always at our command, whether in winter or in summer, by day or by night – it knows no intermission but what our wishes dictate.[23]

These 'machine dreams', which were, more precisely, motor dreams, were by no means an exclusively urban and industrial phenomenon.[24] Agricultural reformers, agronomists, scientists and farmers alike were fascinated by the tireless, continuous movements of the machines powered by steam engines day and night, weekdays and Sundays, summer and winter. In Switzerland, a commentator in an agricultural journal wrote in 1871 that the co-operation between agrarian sciences and technical engineering would lead to the day when the peasant would be nothing more than a 'controlling and intelligent conductor of machines which are subject to his will'.[25] Since the 1850s, when agronomists became convinced that agriculture should and could be modelled along industrial lines, agricultural journals regularly printed reports of 'successful' implementations of the steam engine in France and England.[26] But, significantly, these reports were rather based on public demonstrations than everyday practice, and they often illustrated more the aspirations of agricultural reformers, scientists, engineers and mechanics than the everyday reality in the fields.[27] Nevertheless, it became common to expect that the transfer of motorised technology from the industrial workshop to the field and barn of the farm would lead to similar effects here as in industry and that agriculture would soon be transformed from an 'empirical handicraft' into a 'science-based' industry, as the agronomist and farmer Albrecht von Fellenberg-Ziegler wrote in 1865.[28] The steam-based motorised technology in industry, therefore, set an ever moving 'horizon of expectation'[29] for the transformation, rationalisation and scientisation of agriculture into operation.[30]

When it came to adopting the steam engine into agricultural practice, however, it soon became evident that things were much more complicated. The 'progressivist fervour' was consistently brought down to earth when the steam-powered, newly developed machinery crystallised itself as rather unreliable because it was often not capable to adapt to the ever changing conditions.[31] Weather and topographical factors, seasonally and diurnally changing degrees of capacity utilisation and the limited possibilities of modularising and serialising work sequences with living animals and plants often turned the elegant efficient machine of industry into an inefficient monstrosity in agriculture.

Decentralised, soil-based agricultural production apparently required a different form of mobility and versatility from the centralised one in industry: 'Rather than the Copernican revolution of manufacturing whereby nature must circulate around the machine, nature in agriculture maintains its predominance and it is the machine which must circulate.'[32] Mindful observers of the agricultural development in industrial societies like Karl Kautsky and Eduard David had already come to similar conclusions in the late 19th century. In his *The Agrarian Question*, published in 1899, Kautsky wrote that the introduction of machinery in agriculture faced 'more obstacles than the mechanisation of industry'. Whereas 'the industrial workplace, the factory, is an artificial creation, adapted to the requirements of the machine', in agriculture 'most machines have to work in and adapt to natural surroundings'. Kautsky, one of the strongest supporters of a scientisation and industrialisation of agriculture, even admitted that it was 'often difficult, and occasionally downright impossible'.[33]

The only undisputed, truly successful application of the steam engine in 19th-century agriculture was the threshing machine.[34] Here, significantly, the power of the steam engine was not used to facilitate the *production process*, but, as in industry, for the *transformation* of a *product*: cereals into grain and straw.[35] Thus, the use of the steam engine proved to be advantageous only for stationary belt-work. For almost all other activities and especially the fieldwork, the diversity and the specific temporal and spatial structures of the tasks required a more mobile and flexible source of power. Thus, when steam engines were actually used beyond their fixed place in the farmyard, they had to be installed on wheels and pulled by animals in order to fulfil the requirements.[36] The steam engine, therefore, did not replace draught animals in agriculture – quite the contrary: for almost a century their numbers on the farms rose significantly. Because draught animals remained even on farms where tractors were bought too, in agriculture a hybrid energy system emerged which remained firmly within the biosphere and demanded a congenial co-operation between humans, animals and motors.

The problems created by the attempts to adjust the steam engine to agricultural conditions led not only to an increase in the numbers of draught animals but also to a new intellectual interest in them, which representatives of the emerging industrial societies had somewhat prematurely perceived as a 'pre-industrial' phenomenon.[37] Hence, agriculture not only witnessed a disenchantment in the attempts to motorise its production, but also a shift of the intellectual attention towards animals which could be bred, fed and trained to work in co-operation with human beings: horses, mules, donkeys, oxen, cows, bulls and dogs. Peasants, agronomists, veterinarians and engineers began to view the body and mind of draught animals increasingly as an 'epistemic

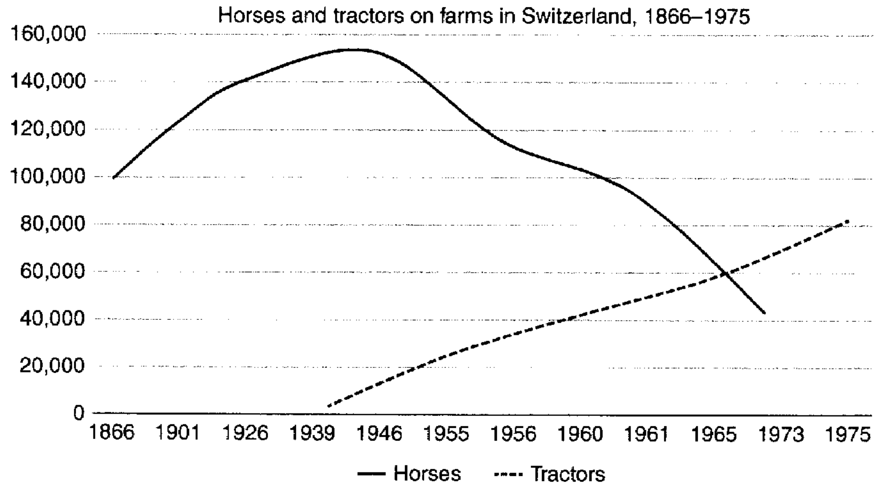

Figure 8.3 Horses and tractors in Swiss agriculture, 1866–1965

Source: Heiner Ritzmann-Blickenstorfer: Land-und Forstwirtschaft, in: Idem (ed.), Historische Statistik der Schweiz. Zürich 1996, pp. 513 and 575.

object', worthy of elaborate and sometimes expensive observations, studies and scientific experimentations.[38] 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 draught animals. Not surprisingly, this process led not only to the creation of 'new' breeds, but also to the disappearance of others.[39] Veterinarians 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. Farmers sharpened their long established hermeneutic culture of observation of the behaviour of the animals which mostly lived under the same roof, often crediting them with qualities so far reserved for human beings, such as character, memory and capacities to learn.[40] 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.[41]

The heterogeneity and complexity of tasks to be done in agriculture produced a remarkable variety of energy structures on the farm: steam and stationary combustion engines were used along with electric, animal and human power.[42] But electricity, like steam, was a spatially (too) fixed source of energy for fieldwork; it too remained confined to the farmyard where it was introduced on a large scale in the first half of the 20th century. As a source of energy circulating in network structures, the distribution patterns of electrification depended heavily on the activities of electricity works and collective decisions made by local communities and regional political institutions.[43] As predicted by contemporary observers like Fellenberg-Ziegler, mechanisation alleviated many operations on the farm, but it also created a demand for new skills and knowledge, and it did not save labour to a significant extent. Instead, it shifted labour mainly from humans to animals who 'could push, pull or drive with their legs and feet by using the motion of walking or trotting' and thus convert their 'linear motion into the kind of power needed for the machine'.[44]

Animal motors and iron horses: the intellectual fascination for draught animals and their influence on technological change

The close interplay between men and the increasing number of draught animals and machines created a conceptual dialectic between the animal and the motor in many of the agricultural discourses on labour and technology in the age of the second industrial revolution. At the same time as the human body was increasingly conceptualised as a 'human motor', as Anson Rabinbach has shown, the animal body had become an animal motor in the eyes of the actors of the agrarian–industrial knowledge society.[45] In the language of thermodynamics, which governed much of the late 19th- and early 20th-century

thinking on labour, productivity, technology and energy (and which linked discourses in physics, engineering, economics and agriculture), all productive activity was linked interchangeably in the concept of energy.[46] The implications of this spread of thermodynamics in scientific discourse were aptly summarised by François Jacob:

> The concepts of thermodynamics completely upset the notion of a rigid separation between beings and things, between the chemistry of the living and the laboratory chemistry. With the concept of energy and that of conservation, which united the different forms of work, all the activities of an organism could be derived from its metabolism ... the same elements compose living beings and inanimate matter; the conservation of energy applies equally to events in the living and in the inanimate world.[47]

At the same time it is important to remember that the two main laws of thermodynamics experienced a rather asymmetrical reception in scientific discourse. While the first law of thermodynamics stated that matter and force can be exchanged and converted but neither created nor destroyed, the second law of entropy, however, insisted on the irreversible dissipation of energy in the production process. While the first law in combination with the access to the resources in the lithosphere fitted perfectly into the concept of eternal growth and progress, the second was a rather uncomfortable and, therefore often ignored, reminder of the limits and costs of growth in an 'energy-rich economy'.[48] This asymmetric reception proved to be of crucial importance for the conceptual amalgamation of animals and motors, because it obscured the difference between living and inanimate matter, as François Jacob emphasises. Only from this rather reductionist point of view could humans, animals and motors equally be reduced to means of energy transmission.[49]

The levelling of the differences between living beings and inanimate matter in the thermodynamic concept of energy corresponded, not surprisingly, only partially with the experiences of the farming population which lived and worked in community with their animals.[50] The peasants were too well aware of the fatigue of their working companions, their need to rest, their intellectual adaptability and their changing performance capacities depending on the cycle of reproduction to be ignorant of the fundamental differences between motor and animal. The practical and tacit knowledge of the farming population rather supported the insight of the agronomists that draught animals and electric and combustion motors showed both similarities, but also striking differences. Therefore, the emerging discourse on the 'farm power question' was by no means structured by an antagonistic pattern, pitting the draught animal against the motor and operating in an either/or mode of discussion.[51] Rather, animals and motors were more and more conceptualised as complementary tools. Consequently, farmers and agronomists began to identify operations which should best be done with the help of animals and operations where the use of engines was more efficient. Franz Ineichen, a farmer and pioneer of motorisation in Swiss agriculture, brought this perspective to the point when he wrote in 1941 that every source of power on the farm was 'suitable for some tasks and causes trouble for others'.[52]

Both sources of energy, animals and motors, were identified as epistemic objects to be developed in order to meet the diversity of tasks, and the patchy temporal and spatial structures of agricultural work. This process of improvement occurred by mutual observations and conceptual transfers of insights. Just as the metaphor of the animal motor provided a means for thinking of the animal body in an analogy to the engine, the development of suitable agricultural technology drew on the animal body as a source for intellectual inspiration. Quite tellingly, the successfully implemented motorised machines were increasingly perceived as 'iron horses' or 'modern superhorses',[53] a metaphoric and semantic indicator that the machine–animal relation was not a cognitive one-way street, shaping solely the perception of the animal along the lines of the engine, but rather a dialectical process producing heuristic and epistemic effects in both directions.

This comparative cognitive pattern between animal and motor had profound implications on the specific development of technological innovations in agriculture in the first half of the 20th century, which received a first boost in the second half of the First World War, when a large proportion of the agricultural horses were required for military purposes. In Switzerland, the campaign for an 'advancement of a rational motorisation' began in 1916/17.[54] But the laborious and expensive attempts to find a tractor suitable to agricultural conditions were mainly unsuccessful, since they were still more or less the same technical 'monsters', 'leviathans' and 'behemoths' which Siegfried Giedion and other historians identified in North America around the turn of the century.[55] Only the new agricultural tractors, developed in the interwar period, successfully acquired some of the qualities the analytical eyes of agronomists and veterinarians so aptly captured in their close inspection of the animal body. The agronomist and promoter of motorisation of agriculture in Switzerland, Hermann Beglinger, set the pace of development when he declared in 1920 that the tractor of the future would have to correspond 'to a higher degree to the horse' than it had so far.[56]

From the 1920s on the language of motor-technology began to shape the perception of the animal more profoundly. Agronomists claimed that the capacity of the horse to keep its pulling power and speed constant despite an uneven road or wet soil was about the same thing as 'continuously variable transmission' and 'changing gears' in motor-technology.[57] The agile movements and speed variations of the animal body were captured with concepts such as 'motoring torque' and 'gears'. Hooves became 'pneumatic tyres' and were analysed with regard to their 'adhesion', and instead of trotting and galloping the horse had certain 'driving and guiding characteristics'. For the agronomist Emil Rauch it was clear that the horse 'changed gears' and raised the 'adhesion' depending on the conditions of the terrain and the tasks to be done, thereby showing an adaptability, agility and flexibility the tractor was

not yet able to compete with.[58] In a sense, then, the animal became at least in the conceptual realm of agricultural technology something of a cyborg.[59]

This blurring of spheres had the reciprocal effect that the animal's body and mind became a model for the development of new and improved agricultural machinery. As long as the tractor showed such deficiencies regarding its adaptation to agricultural conditions, draught animals were kept even on those farms which had bought tractors. In the everyday experiences of the farming population, the specific capabilities of the animals continued to reveal the technological shortcomings of the tractors. Thus, the necessity to blend the speed, mechanical precision, steadiness and timeliness of the already existing tractors with the versatility and diversity of skills displayed by the animal became an intellectual driving force for the agro-technological improvers, whose developments of innovative technology were chiefly the result of a close co-operation between farmers, agronomists and engineers, as can be seen in the great variety of agricultural machines developed around the capacities of the draught animal.

In analogy to the animal body and mind, technological innovations were increasingly directed towards a multifunctional usability, combining different motors for specialised tasks within the same machine. In other words, the challenges of developing technologies suitable to agricultural conditions led many observers to the firm conviction that the longed for self-propelled, motor-driven universal and general-purpose tractor had to have the qualities of most draught animals too, in order to replace them eventually.

Figure 8.4 An industrial technique adapted to the power available on the farm: a partly motor-powered mowing-machine in the interwar years

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Extending the energy base: access to the lithosphere and the motorisation of agricultural production in the 1950s

The 1950s are characterised by an accelerated period of change in agriculture, based on an interplay of historical experience, new access to mineral resources, rapid technological development, shifting political conditions and the production of new as well as the marginalisation of hitherto 'useful knowledge'.[60] The old attempts to develop a tractor shaped along the multifunctional lines of the draught animal while simultaneously transcending its constraints, limitations and peculiarities made its breakthrough in the 1940/50s, and, therefore, created the conditions which enabled a broad and rapid diffusion of the now versatile motorised technology. Tractors were, of course, an important topic in agricultural discourses since the first decade of the 20th century, but their application remained mainly restricted to pulling purposes. This rather slow implementation of a technical innovation often frustrated contemporaries, and is often interpreted by historians as proof of an assumed conservative character of farmers when it comes to technology. Our reading suggests that this fractured process of technological implementation was a crucial experience for the actors involved; it created the cultural dispositions, knowledge and skills which eventually led to an accelerated adaptation of the more versatile tractors when they entered the stage in the postwar years. It was exactly the complex and unpredictable experiences with new technologies that created the epistemic breeding ground which enabled farm labourers as well as farmers to creatively cope with the challenges of the tractors and a whole range of other motor-powered machines in the 1950s. Now the 'monsters' of the early 20th century and the 'steel-horses' of the 1930s were finally turned into 'a power centre of the farm',[61] equipped with the crucial power take-off that eventually made it possible to multitask, the ultimate precondition for its superiority over the draught animal, as predicted in the early 1920s.[62]

It was this technological breakthrough that empowered agriculture to participate in a so far unprecedented degree in the consumption of mineral resources, making the reproduction of biotic ones superfluous to a large, but by no means total, extent. This access to the lithosphere 'liberated' farmers partially from the temporal and spatial restrictions bonded to the use of living matter and enabled agricultural production to catch up with growth rates which had characterised the industrial sector since the 19th century. Contrary to popular perception of a stagnating sector, Giovanni Federico recently pointed out that 'the productivity performance of agriculture during the postwar boom was outstanding. From 1967 to 1992, its rate of TFP (Total Factor Productivity) growth from 1967 to 1992 exceeded the rate in manufacturing in seven Western European countries out of eight and the average difference was 94 per cent'.[63] But the main causes for this economically extraordinary (and ecologically far-reaching if not disastrous) performance lay less in a new interventionist agricultural policy, as Federico and many others suggest,[64] than in a multitude of close epistemic, institutional, technological and political interactions within the new extending energy base of the 1950s. Certainly, the Second World War accelerated the already comprehensive state interventions with the newly emerging credit and knowledge institutions. And the re-creation of agriculturally relevant international institutions and the American-based technological improvement programmes after 1945 equally supported the implementation of the now technologically improved tractors and other motor-powered agricultural technology. But these institutional, technological and political factors only produced the profound changes in agriculture in the context of the rapidly extending energy base that characterised the 1950s as a decade of a hitherto unknown growth of production and productivity in agriculture. Particularly crucial for this age of transition, therefore, was the replacement of one natural resource, the reproducible plants and animals, by another, the consumable minerals which have a much bigger growth potential (in the short term) than the biotic ones. In other words, the extension of the energy base 'disintegrated' the energetically so far partly self-supporting farm while it integrated the agricultural sector into the growth paths typical of industrial-capitalist societies since the 19th century.[65]

A crucial factor for the growing output and productivity in agriculture was that the broad diffusion of the tractor and other motorised technology unleashed land so far used for the feed and upkeep of draught animals, and breeding bulls, which were replaced by the rapidly expanding technique of artificial insemination. Moreover, farm labourers were no longer needed to handle the draught animals and to do work which was now superfluous because of the multifunctional versatile tractor and the application of chemical aids in plant production.[66] Thus, the tractor not only facilitated work, but it also made labour superfluous and provided large land areas which were now used for producing food and commodities for the agro-food industry.[67] Whereas in the age of mechanisation the increasing number of draught animals simultaneously promoted and limited growth, in the age of motorisation agriculture for the first time was able to meet the growth expectations of industrial societies. The process of tractorisation integrated the sector into the industrial economy by 'disintegrating' the farm from its former partly energy independence.[68] The necessity to buy fuel, replacements, artificial fertilisers, seeds, semen, etc. exposed farmers to the hitherto unknown volatilities and uncertainties of the markets, and the disappearance of draught animals deprived them of a part of their reproducible means of production. In short, when capital and mineral resources replaced labour and biotic resources, the production was decoupled from its former self-supporting, but growth-restricting system of a partial reproduction in the process of production. The farm, in other words, was transformed from a semi self-supporting unit to a crucial, but still vulnerable, link in the chain of the growing agro-business. It was primarily the anxiety to safeguard the stability of agricultural production, still subject to changing weather conditions and cyclical and seasonal patterns of production, which promoted the new state interventionism of the 1950/60s, rather than the often more lamented than analysed farming lobby.[69] This process of disintegrating the farm by integrating the agricultural sector into the capitalist economy has often been reduced to the single aspect of labour being replaced by capital. While this interpretation is not entirely wrong, it nonetheless obscures more than it enlightens the fundamental changes which characterised agricultural production in the 1940/50s: the replacement of biotic resources by mineral ones.

The predominant view of these changes in the postwar years usually emphasises the financial costs for the taxpayer and the beneficial results of the process of rapid modernisation that turned food shortages into food surpluses. Contemporaries were fascinated by the new possibilities which opened up thanks to access to the lithosphere. The problems that went hand in hand with this appropriation of new energy stocks for agricultural production, however, were for the time being mainly concealed behind the veil of prosperity, emancipation from drudgery, unexpected growth of production and productivity, and rising living standards. To some extent, it might have been the unfamiliarity and the sheer speed of the changes in postwar agriculture which led many observers to endorse the unprecedented powers of production and, at the same time, to neglect the ecological problems associated with them.

As profound and far reaching as these changes undoubtedly were, it is important to remember that they did not free the agricultural sector from the growth restrictions of an organic economy entirely. Even in the age of a new wave of 'industrialisation', agriculture still used animals and plants that contested their industrialisation and commodification to a certain degree, and, therefore, reminded the public not only that there would be alternative forms of agricultural modernisation to the comprehensive attempts to industrialise it, but also that modernised agriculture is something quite different from simply industrialised agriculture. Nicholas Georgescu-Roegen had already realised this in 1960 when he wrote: 'For industrial uses man has been able to harness one source of energy after another, from the wind to the atom, but for the type of energy that is needed by life itself he is still wholly dependent on the most 'primitive' source, the animals and plants around him.'[70] The transition process of the 1950s, therefore, created the possibilities of gaining access to new sources of energy which were used to a large extent by the farming population, but it did not lead to an escape, from an industrial perspective, of the peculiar structures and growth restrictions of biotic resources.

Conclusions

The third agricultural revolution of the long 1950s, which Paul Bairoch aptly characterised as 'the industrialisation of the agro-food-chain',[71] was by no means the outcome of a historically inevitable process of technological change, but rather the historically contingent result of a complex interplay between resource-bound, epistemic, technological, political and institutional forces. The 1950s were indeed a caesura with regard to both the use of energy in agriculture and the epistemic framework in which the newly gained access to

mineral energy was interpreted. The motorisation of agricultural production based on the access to a *store* of energy in the lithosphere unleashed an unprecedented potential of production thanks to the new knowledge created and accumulated by the actors of the agrarian–industrial knowledge society in their long enduring efforts to motorise agriculture. Significantly, this process went along with the marginalisation of the hitherto essential knowledge about the characteristics of the energy *flows* of biotic resources reproducible with the help of the photosynthesis. The long 1950s witnessed an epistemic shift away from an intellectual occupation with the temporal and spatial logics of living resources to a scientifically supported 'decontextualised rationality' that derived its concepts chiefly from industrial realities which were placed above agricultural realities.[72] Not surprisingly, therefore, the distinction between the characteristics of the reproducible biotic resources and the idiosyncrasies of the consumable fossil resources almost completely vanished from the discourses in agricultural science in that period.[73]

A historic-epistemic approach towards change and continuity in agriculture reveals that the practical outcomes of technological developments are by no means the result of a more or less 'frictionless'[74] diffusion process, nor can they be solely traced back to agricultural policies or institutional frameworks alone. Our approach rather suggests a preponderance of a multitude of close interactions of theory and practice; scientists and farmers both conceptualised 'their' object along the lines of the other. In the case of the key invention of the

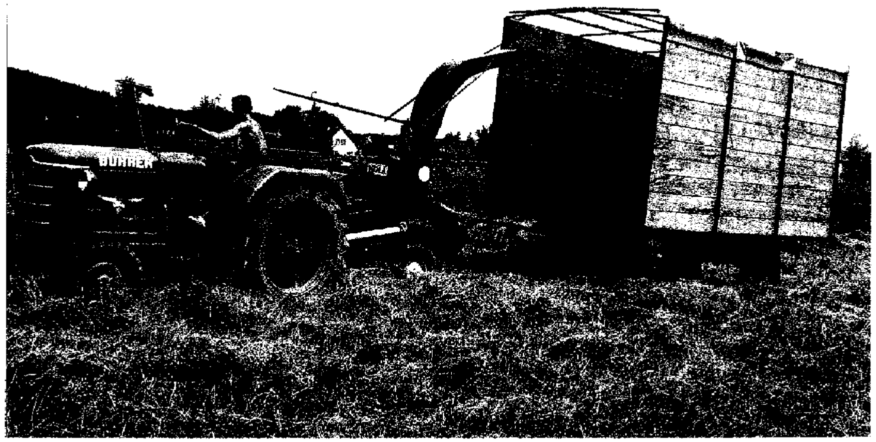

Figure 8.5 Only the development of the power take-off and its perfecting in the 1950s made the tractor 'a power centre of the farm', enabling it to multitask

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tractor, technology not only transformed and conquered nature, as the standard progressivist narrative of technological change in agriculture maintains, but the understanding of the nature (and culture) of the animal shaped technological improvements in a reciprocal way. A history of technological change in agriculture, therefore, has to pay more attention to the social and epistemic interactions between humans, animals and motors – interactive relationships that have been hidden from history for all too long.

The peculiarities of technological change in agriculture are heavily influenced by the spatial and temporal characteristics of agricultural production. Farms, therefore, were (and still are) characterised by a hybrid energy resource system with the result that agriculture became (almost) like industry while it (partly) remained different. To identify and recognise this hybridity as an empirical fact enables us to do historical justice to the creative *bricolage* (Claude Lévi-Strauss)[75] that the farming population revealed in the use of different energy resources in their daily work – so aptly illustrated by the rise of draught animals in the age of steam and the simultaneous transformation of monster-tractors into steel horses first and then versatile, multifunctional oil-fuelled tractors equipped with power take-offs.

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9 Technology policies in dictatorial contexts

Spain and Portugal

Daniel Lanero and Lourenzo Fernández-Prieto

The 1930s and 1940s were a time of agrarian fascism in the Iberian Peninsula. The influence of international fascism on agriculture and the rural world materialised in a series of core policies that were commonly adopted by the political regimes of various European countries within the fascist ideological sphere. These policies were characterised by economic intervention in every phase of agriculture, from production to commercialisation, preference for technical agricultural reform (colonisation policies), inclusion of the rural population in mass organisations, and a discourse that exalted the ethical and moral virtues of the rural world. The agricultural policy of the Portuguese Estado Novo operated within these parameters from its establishment in 1933 until the end of the Second World War. Similarly, in Spain this period began with the adoption of certain measures by rebel officers in the territories they controlled during the Civil War (1936–1939) and extended until well into the 1950s.

The Estado Novo and the Franco regime constitute two privileged historical laboratories for examining the transition from the scientific, technocratic and authoritarian modernising push of agrarian fascism to the agricultural modernisation paradigm implemented in Western Europe after 1945, which was adopted later by the Iberian dictatorships. The common elements and continuities between these models are much more relevant than a first glance would indicate.[1]

Broadly speaking, this panorama provides the backdrop to the 1950s, which is the stage we will address in this text in three sections. In the first and second sections, we analyse the evolution of agriculture and agricultural policies in Spain and Portugal, respectively, during that decade. Both sections give special attention to technological innovation processes and the role of key actors such as the technical agronomic elites within these dictatorships. The third section provides a comparative synthesis.

The 1950s: a decade of changes in Francoist agrarian policies

Spanish agricultural historiography consistently marks the early 1950s as a significant turning point in the economic policies of the Franco regime. This

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