Farming and Agricultural Industrialisation

Martin Bruegel

Bruegel, Martin. "Farming and Agricultural Industrialisation." *Food and Drink in History*. 2020.
http://www.foodanddrink.amdigital.co.uk/ResearchTools/Essays/Farming

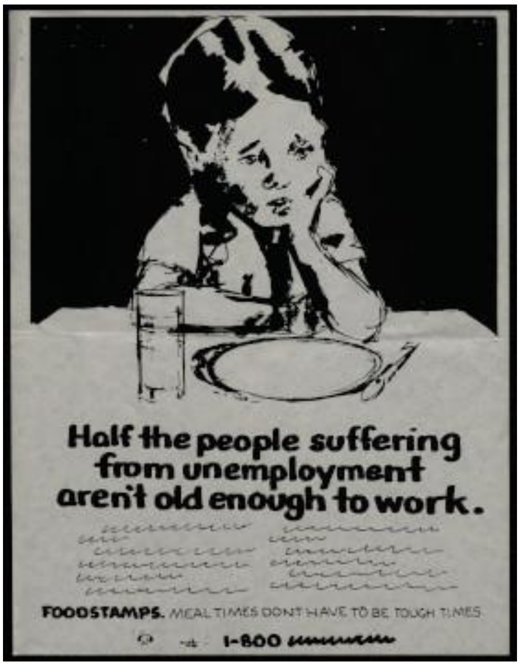
Farming and Agricultural Industrialisation

Martin Bruegel, Institut National de la Recherche Agronomique

The world's population grew from 990 million in 1800 to 1.65 billion in 1900, then jumped to 6 billion in 2000. A bundle of factors pushed demography. While better sanitary conditions improved health, drove down mortality, and enhanced longevity, agricultural development boosted food production. Farming output not only sustained population growth, it outpaced it enough to help increase average caloric intake per head. To be sure, nutritional inequality remains pervasive today. Countries in sub-Saharan Africa and Asia still suffer from inadequate supplies, and food poverty persists in advanced economies [see, for ex., *Hunger in America, 1985*]. However, wars and political upheavals rather than insufficiencies in production explain contemporary difficulties in having access to adequate nutrition.

Total alimentary provisioning over the last two centuries moved available energy per person and per day from less than 2000 calories to 2800. This figure stands for a remarkable achievement. It signals an appropriate overall supply. Today, food furthers rather than limits population growth in general, and augments individual physical capabilites in particular. Two thousand eight hundred calories are also a fitting benchmark in what scholars call the nutrition transition. They usually suggest a shift from a cereal-based diet to a food regime in which products of animal origin, including fats, assume a weighty role. England, France and the United States arrived at, and then preserved, this threshold by 1900. The rest of the world keeps following.

Agriculture proved instrumental in enabling the dietary shift best expressed in the substitution of animal for vegetable proteins in human consumption. According to economic historian Giovanni Federico, agricultural gross output was in line with the rise in population between 1800 and 1870, largely outperformed it before World War I, slowed down in the interwar period, then to take off spectacularly in the second half of the twentieth century when, by the 1990s, obesity turned into a public health problem in the most advanced countries. This section explores how the epochal modifications of the ways in which food was grown contributed to the development of the modern world.



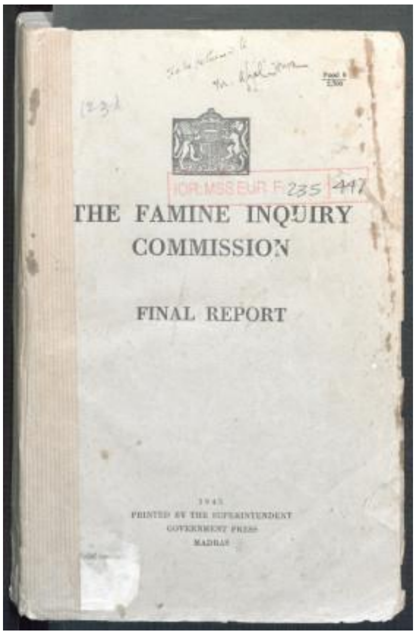
Foodstamps advertising campaign in Hunger in America, 1985 © Material sourced from the Dolph Briscoe Center for American History, The University of Texas at Austin

FARMLAND EXPANSION

Cultivating more land was the method to increase agricultural output in the nineteenth century. In the fifty years before World War I, westward movement doubled the agricultural surface in the United States while the expansion east and south tripled Russia's farmland. Peripheral countries joined the boom as international demand for grains and meat fuelled the agricultural exploitation of the Canadian prairies and the Argentinian pampas toward the end of the nineteenth century. Brazil's arable lands increased tenfold between 1900 and 1950. Water control and canal building in the Mekong Delta quadrupled the area of rice production between 1880 and 1930. Today, agriculture covers roughly 40 percent of the world's land area, one third of which is allocated to crops, the other two thirds to pastures.

The effect of this territorial expansion on world trade was tremendous. Its volume skyrocketed. In the year 2000 international commerce was 75 times larger than in 1850. By 1900, staples travelled far and wide: Great Britain imported wheat from Canada, India, Russia and the United States [on the effects of such trade, see *The Spice Mill*, Vol. 9, Iss. 4]. Argentina supplied the world with increasing quantities of canned and chilled beef. Tropical products like coffee, cacao and also fruit (bananas, oranges, lemons, pineapples) entered markets in such quantities that they lost their status as luxuries [for the diffusion of the banana, see *Food and Cookery*, Vol. 18, Iss. 195].

The extension of cultivated land was, however, not enough to disprove the periodic repetitions of Malthus' glum pronouncements on the world's demographic destiny [see *Famine Inquiry Commission: final report* for the opposition between technological optimists and demographic pessimists in the context of Indian development after World War II]. The English scholar asserted in 1798 that exponential population increase would inevitably outspeed the linear growth in food production (limited, as it were, to disposable surfaces). The discrepancy was to wind up in famine and disease in order to have the demographic pendulum swing back to an equilibrium between human needs and food supply. Technical ingenuity prevented this divergence from happening. All farming activites – from tilling the soil to cultivating crops, from rearing livestock to processing products on the farmstead – benefitted from innovations, large and small, that enhanced productivity. This simply means that the conversion of resources (labour, land, plants, animals, energy) into commodities became more efficient and contributed to increasing outputs. When tractors replaced horses to draw ploughs rather than harrows to break up fertilised land on which a pest-resistant wheat variety would grow, at least four levers helped lift agricultural productivity. Their combination also explains the declining part of farmers in Europe's and North America's population. While half of England's residents tended to feed its total population by the end of the eighteenth century, that ratio was obtained in North and Western Europe by 1900, with Southern Europe following in the first half of the twentieth century. Today employment in agriculture oscillates around 4 percent of the entire workforce in Italy and between 10 and 15 percent in Portugal, Spain and Greece. It currently stands at 1.5 percent in the United States.



Famine Inquiry Commission: final report © Content provided by: The British Library Board. All Rights Reserved.

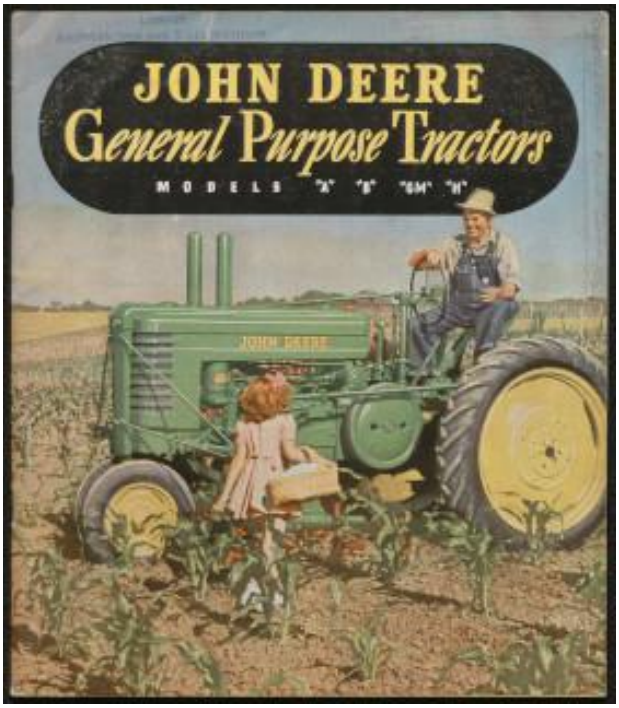
INTENSIFICATION

The drive to increase food production applied itself to the biology of crops and animals, to the chemistry of land, to the physics of implements and machinery, and the organisation of labour. The interaction of these factors of agricultural production is complex, and if analysis tends to look at them separately, technical progress has them go hand in hand more often than not. According to a classic scholarly argument, advances appeared to play themselves out according to a region's relative endowment in labour and land. Mechanisation tended to prevail where land was abundant and labour expensive, that is in North America where new machinery replaced manual work and improved labour productivity. Regions like Europe with an inverse relation appeared to stimulate advances that lifted the efficiency of the land. Yet interaction between these factors is emphasised by historians Olmstead and Rhode, who did much to promote the term "biological innovation" to designate improvements in seed, cattle and feed. Geographic expansion, they say, usually depended on new or enhanced plant varieties or animal breeds because cultivation or animal husbandry under different, often harsher climates and in poorer soils required the selection of more robust seedlings and hardier livestock. Russian wheat, American maize or Spanish Merino sheep flourished in Canada, Southern Europe, the Hudson Valley and Australia [see the reflection in *Orange culture in California*]. Note that a geographic imperative presides over every agricultural innovation: local circumstances often induce modifications in tools. In other words, adaptation is a condition of the adoption of new means of production [see, for example, the trials to cultivate rice in Australia, *Rice cultivation, 1949-1950*]. The nature of the soil, for one, determines the kind of plough best suited to break it [on the tremendous variety of ploughs, see *Charles V. Mapes' illustrated catalogue of plows*, pp. 1-7, 20-72].

The profitability of innovations tends to depend on the size of an enterprise. A greater endowment in capital and consolidated land holdings permit so-called economies of scale that favour the adoption of new agricultural tools and methods; the investment is small when measured against the anticipated gain. In the course of the last two hundred years, the family farm – where land was a legacy, production varied, working skills were wide-ranging but capital scarce – receded in the face of agricultural businesses for which the soil is an asset, uniform production the rule, competence quite narrowly specialised, but capital and credit within easy reach.

A. Mechanisation: Agricultural labour processes often consist in a series of repetitive tasks. Scythes substituted for sickles in wheat harvesting after 1800. The gain of speed and harvested surface exceeded the cost of higher wages and of grains lost to shattering as a result of the tool’s impact (there were other incidental parameters like the uses of stubble for fertilizer or fodder and of straw for fodder or thatching). The introduction of the scythe to mow grass proved speedier as there was no loss of grains. The change affected the sexual division of labour: the dexterity that women showed in handling the sickle destined them to the secondary, lower-pay jobs of raking and binding behind scythe-swinging men (in North America, a cradle attached to the scythe facilitated binding the sheaves).

It took trial and error for mechanical devices to replace manual harvesting and mowing work by the 1850s. A shortage of hands during the American Civil War impelled farmers to buy mechanical reapers. Their use became common in England around 1900 but lagged in continental Europe where the scythe remained the main implement. When the three tasks of cutting, raking and binding were ingenuously integrated into one operation effected by the so-called "combine", mechanisation was complete. However, the machine was at first so unwieldy that the widespread employment of a downsized model depended on the development and diffusion of tractors in the 1920s [on general purpose tractors in 1945, see *John Deere general purpose tractors: models "A", "B", "GM", "H"*]. Combines were the future, though, and by the 1950s they also harvested oats and soybeans. Threshing, the separation of the grain from the stalk, followed a very similar chronology at a few years' distance, and with impressive consequences: a farm hand, male or female, can thresh from 20 to 40 kg of grain per hour while a mechanised thresher can process 1.5 to 2 tons in the same time today [to get a sense of such mechanics, see *Rice cultivation, 1949-1950*].



Mechanisation thus raised two major issues: they concern, first, the source of energy to fuel the new technology, and, second, the match between machine and environment. Animals had long drawn ploughs, of course, but combines required a large number of horses. They, in turn, needed to be fed, an additional claim on agricultural land which stood at one quarter of the cultivated surfaces in the United States during the opening decades of the twentieth century [for an early reflection on the trade-off and its implications for our diet, see *Food & Cookery Vol. 33, Iss. 355*]. The obstacle disappeared when tractors got smaller, more maneuverable, and – thanks to the industrial assembly line – cheaper. Yet it was, once again, a bottleneck in the supply of labour that stimulated their diffusion in the United States where horses were too few to cultivate the land necessary to feed people and army during World War I: the number of tractors climbed sharply from 1000 to a million between 1913 and 1930 (land used to feed horses was converted toward other purposes, often dairy farming). Western Europe trailed behind with 200,000 tractors on the eve of World War II as the cost of labour remained low and the Great Depression put a break on investments. Horsepower still fuelled 85 percent of agricultural field work in 1950, but by then the mechanical take-off was on its way. The area counted two million tractors equipped with internal combustion engines by the mid-1950s. They saved both labour and land, which goes to show their versatility as they eased any kind of field work and contributed to the acceleration of transport.

Electricity provided similar flexibility. In Europe, where rural electrification had started before the nationwide New-Deal programme in the United States, smaller, stationary devices like the centrifugal milk separator replaced hand-cranking to obtain the cream necessary for buttermaking. It was a device that improved the quality of the end product, relieved women from backbreaking dairy chores, and eventually removed milk processing from the farm where power coolers helped preserve the liquid's freshness until its conveyance to a factory [for an illustration and explanation of one of the first improved cream separators, an invention hailing from dairy vanguard Denmark, see *The Reid improved Danish separator*]. Milking machines existed by 1905, but it took more than a generation to hook them up to the electric grid.

Efficiency gains motivate attempts at the mechanisation of the different steps in agricultural production processes. The major innovations are easily listed, and in many respects they all aimed at integrating the gamut of harvesting operations (machine seeding was the other side of the coin). Mechanical potato diggers dated from the 1870s and were adapted, with limited success, to sugar beets by the 1930s with the goal of building a combine that would cut tops, lift the beet out of the soil, and load it onto a wagon; the prowess was achieved only by the 1950s. Tropical sugar, too, was subject to combines that cut, loaded, and transported the raw canes to mills to get crushed by the 1930s. Economist Binswanger tabulated productivity indicators to assess agricultural progress in the United States over the twentieth century, and his data show that the time farmers spent on an acre of land planted with maize diminished by a factor of ten, with wheat by a factor of five, with potatoes by a factor of two [see, for the interaction of different factors, *Culinary menu: Colorado, 1906-2005*], and per milk cow by a factor of three between 1915 and 1975. At the same time, yields increased everywhere.

B. Biological innovation: New plant varieties and animal breeds enhanced nature's productivity in behalf of the world's population. Before the recovery of Mendel's insights into genetics toward the end of the nineteenth century, empirical selection helped reproduce desirable characteristics in crops and livestock [see on early breeding successes, *The Spice Mill* Vol. 13, Iss. 4]. The beet is a case in point as such practices drove up its sugar content from about 5 to 17 percent in the course of one hundred years. Another successful innovation was the grafting of phylloxera-resistant American vines onto European varieties after chemicals or farmers' remedies had been incapable of defeating the insects feeding on native grapevines. Animals were selectively bred for desirable traits: cows that would give more milk or develop a higher proportion of muscle for meat; the combination of wool and fat growth animated sheep breeders; and pigs were bred to fatten until recently when consumers began to demand leaner meat. In any case, the production of animals for consumption has outpaced population growth by 50 percent.

With scientific knowledge safely in hand by World War I, breeders set up controlled experiments on a great many varieties and species. Work on what was to become broiler chickens known for their fast growth started in 1916 [see, for a rags to riches story in the chicken business, *Quick Frozen Foods* Vol. 21]. The paradigmatic story of plant breeding concerns hybrid maize, first marketed in the 1930s. It featured a number of desirable traits: its uniformity made machine harvesting easier; its high yield was attractive to farmers; hybrids proved quite resistant to drought (remember, this happened during the Dust Bowl); they could be adapted to various habitats and lengths of growing seasons. These advantages made for rapid diffusion in the American corn-belt. Within less than 10 years, more than 90 percent of corn grown in Iowa was of hybrid origin. That level was reached in the late 1950s for the country as a whole. In general, certain characteristics were sought-after because they enabled industrial processing. It took dimensional homogeneity and robustness to apply machines to fruit and vegetables. Variability and frailty slow (or rule out) industrial processing [see, on machine- and hand-harvesting of tomatoes, *Heinz Film: Focus on food*, at 14:00 minutes].

Selection aimed at similar characteristics in wheat. Farmers looked for higher yields, disease resistance, and robustness in the face of meteorological extremes (cold and drought). This was exactly the programme of the so-called "Green Revolution." Its goal was, in the 1950s and 1960s, to transfer modern agricultural technology and associated farming practices to developing countries where hunger was common. Financed by private foundations, agronomists introduced high-yielding cereal hybrids, first short-stalked wheats in Mexico, later rice in India and Africa. These cultivars facilitated the use of mechanical implements, their cultivation often induced prior irrigation projects. Cereal production doubled in the space of generation in the developing world, and it thus greatly contributed to the alleviation of hunger. However, cultivation relies heavily on chemical fertilisers and pesticides, as a consequence of which biodiversity and health decline in the areas where intensive cash-crop agriculture now dominates.

C. Chemical contributions: The success of agricultural science in explaining the nutritional needs of plants and animals led to the increased reliance on synthetic fertilisers (to offset resource depletion). The German chemist Justus Liebig (1803-1873) had by the 1840s demonstrated the importance of nitrogen, phosphate and potassium to the physical growth of living beings [see an example of an element limiting pastures in Australia, *Summaries of statistics and intelligence*]. The discovery helped solve the age-old conflict over land use between wheat-growing and cattle breeding. Natural fertilisers like guano from South America or potash from Germany increased crop yields without the need to extend areas allotted to animals and their feed [for a discussion of the relative merits of organic and mineral fertilisers, see *Charles V. Mapes' illustrated catalogue of plows*, pp. 242-245, or *Lister Brothers' standard fertilizers*]. Like all natural resources, accumulated bird and bat excrements were limited, and the anticipation of their declining availability fired up research into synthetic substitutes. Chemists Fritz Haber (1868-1934) and Carl Bosch (1874-1940) developed a process to convert nitrogen present in the atmosphere into synthetic nitrate, or ammonia. Its industrial exploitation after World War I launched the sale of an inexpensive and quasi inexhaustible chemical fertiliser to farmers and so sealed agriculture's industrial transformation. It is now the most used chemical compound in agriculture. Note that high-yield hybrids are bred to absorb nitrogen efficiently, whether it is fixed naturally by legumes, delivered via manure and compost, or comes in the form of a synthetic.

Another line of chemical research dealt with pest, weed and disease control. Monocultures, whether in flora or fauna, are particularly vulnerable to biological disorders. In the early nineteenth century, Bordeaux winegrowers sprayed copper-based mixtures on their vines to destroy parasites [for empirical pesticides used by California citrus growers at the end of the nineteenth century, see *Culture of the citrus in California*]. But the watershed in their uses lies in the 1940 when synthetic pesticides like DDT and other herbicides were shown to kill off harmful organisms like insects or invasive weeds. DDT's toxicity spilled over, however, on the environment and human health, so much so that certain countries curbed or prohibited its use [on early health concerns, see *California citrograph, Vol. 31, No. 11*].

Pharmaceuticals were introduced in livestock farming to cure sick animals. The administration of antibiotics to animals after the 1940s aimed at preventing the spread of infections. An unintended consequence consisted in the faster weight gain of cattle, pigs and poultry on less feed. The industry welcomed the discovery and used the treatment as a way to increase production. Side effects on animal and human health entered public conscience later, though earlier than we tend to think [for worries in the 1950s about pesticides in the industry, see *Heinz film: Food development*, at 3:50 minutes].

CONCLUSION

The industrialisation of agriculture over the last two centuries led to tremendous increases in food production. Mechanisation has driven up the productivity of labour just as biological and chemical knowledge has made land much more fruitful and animals much more industrious. Their combined effects helped avert malnutrition and famine. However, such progress has not succeeded in closing the gap in food security between industrialised and developing nations. And its ecological cost, it is now realised, has been so high as to undermine not just its future, but the future of humanity as we know it. Intensification came with an ever higher reliance on fossil fuels: food production now requires more calories than it eventually delivers to consumers. Selective breeding generates desirable characteristics for consumption, but it often engenders health defects in animals and a decline in their welfare. It also reduces the biodiversity necessary to our survival. It makes crops, flocks, herds and ultimately humanity more susceptible to pests and disease. Agricultural research thus looks for methods of production that, first, do not deplete natural resources and, second, guarantee the well-being of all.

SELECTED BIBLIOGRAPHY

Adelman, Jeremy, *Frontier development: land, labour and capital on the wheatlands of Argentina and Canada, 1890-1914* (Oxford, Clarendon Press, 1994).

Bairoch, Paul, *L'agriculture dans les pays développés, 1800 à nos jours: production, productivité, rendements* (Paris, Economica, 1999).

Binswanger, Hans, "Agricultural mechanization. A comparative historical perspective," *The World Bank research observer* 1/1 (1986), 27-56.

Bray, Francesca, *The rice economies. Technology and development in Asian societies* (Berkeley, University of California Press, 1994).

Federico, Giovanni, *Feeding the world. An economic history of agriculture, 1800-2000* (Princeton, Princeton University Press, 2005).

Grigg, David, *The transformation of agriculture in the West* (Oxford, Blackwell, 1992).

McClelland, Peter D., *Sowing modernity. America's first agricultural revolution* (Ithaca, Cornell University Press, 1997).

Olmstead, Alan L., Rhode, Paul W., *Creating abundance. Biological innovation and American agricultural development* (New York, Cambridge University Press, 2008).