The Green Revolution

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Mechanization dovetailed with the Green Revolution, was a crucial departure in agriculture that depended centrally on plant breeding. The Green Revolution was a technical and managerial package exported from the First World to the Third, beginning in the 1940s but making its major impact in the 1960s and 1970s. It featured new high-yielding strains of staple crops, mainly wheat, maize and rice. Plant geneticists selected these strains for their responsiveness to chemical fertilizer and irrigation water, for their resistance to pests, and eventually for their compatibility with mechanized harvesting. Success required new inputs, new management regimes, and often new machines. The great triumph came with dwarf wheat and rice, which could hold up a heavy, grain-packed head without bending or breaking the plant stalk. Like the great political revolutions of the twentieth century, the Green Revolution drew intellectually mainly from the Western world, changed its forms when it spread elsewhere, and led to unexpected consequences.

Dwarf wheat, although finally created in Mexico with American money and expertise, had deep roots anchored in the work of an Austrian monk and Japanese agronomists. The mathematical genetics of Gregor Mendel (1822–1884), lost for decades after he published his work, was rediscovered in 1900. Scientists around the world took note, including those at work on rice and wheat breeding at the agricultural research stations sponsored by Meiji Japan. There the Ministry of Agriculture and Forestry had organized crop breeding research in the 1880s. At a time when land hunger turned many peasants into emigrants and politicians into imperialists, the ministry

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* Extracted from J.R. McNeill, 2000, *Something New Under the Sun: An Environmental History of the Twentieth-Century World,* Allen Lane, The Penguin Press, London, pp. 219–27.

sought rice and wheat breeds suitable for Japanese circumstances: scarce land, plenty of night soil. In 1925 its research succeeded, producing after many crossbreedings of Japanese and American wheat, a semi dwarf wheat known as Norin 10. (Norin was the ministry's acronym.) The ministry distributed it to farmers in 1935, but World War II came before it had much impact on Japans food supply. In 1946 an agronomist with the U.S. Army noticed Norin 10 and imported it into the United States, where it was further crossbred with wheats in the state of Washington. Norin 10 did not solve pre-War Japan's food problems, but it eventually changed the world (see Hayami 1975; Hayami and Yamada 1991).[1]

American farmers and plant breeders were hard at work on hybrid maize, hoping to concoct higher-yielding and disease-resistant strains. The great Charles Darwin had been among the first to dabble in crossbreeding maize, publishing his results in 1876. American disciples furthered the work and by 1918 it had developed the double-cross,[2] the basis for all subsequent hybrid maize. In 1930 only 1 per cent of U.S. maize acreage was sown to hybrids, but the USDA converted to the new gospel in the 1930s. By 1939 a sixth of U.S. corn was hybrid, by 1950 three-quarters, and by 1970 over 99 per cent. U.S. corn yields rose to three or four times the levels of the 1920s (Mangelsdorf 1974: 211–14; also see Fitzgerald 1990).

The first farmer to make hybrid corn a commercial success was Henry Wallace in the 1920s.[3] Wallace, later Franklin Roosevelt's Secretary of Agriculture and Vice President, took a special interest in Latin America. As a successful farmer who liked to be called the 'father of industrialized agriculture,' he saw great opportunity for applying the fruits of modern genetics to the venerable techniques of farming in Mexico and points south. He helped persuade the Rockefeller Foundation to finance a wheat and maize research centre in Mexico (1941–1943), which soon hired another son of the Iowa soil, Norman Borlaug (born 1914).[4] Borlaug had a fresh Ph.D. in plant pathology when he arrived in Mexico in 1944. By 1953 he had set to work combining Norin 10 with Mexican and American varieties. Over the years he and his associates created new wheat strains that proved enormously responsive to heavy dosages of nitrogen and timely ones of water, and which in some cases were highly resistant, at least initially, to pests and plant diseases.

Borlaug was the father of Mexico's Green Revolution. He won a Peace Prize in 1970 for his plant breeding, and has a street bearing his name in Hermosillo in northwestern Mexico, the heartland of high-yield farming in Mexico. With the help of Ford and Rockefeller money, the United Nations Food and Agriculture Organization (FAO), U.S. Agency for International Development (AID), and other organizations, the revolution spread from Mexico. Its greatest progress came in southwestern Asia's wheat belts, from the Indian Punjab to Turkey, beginning in 1963 when Borlaug sent dwarf wheats to Indian crop-breeding stations. By 1968, 18 countries sowed dwarf wheat (Lupton 1987: 68–9).

Similar developments took place in the Philippines after the 1960 birth of the International Rice Research Institute (IRRI), also sponsored by the Rockefeller Foundation (Anderson 1991). Using dwarf rice strains first selected by Japanese breeders in the 1920s in Taiwan (then a Japanese colony); rice geneticists created high-yield rice varieties that combined the best features of tropical (*Indica*) and temperate (*Japonica*) rice. By the late 1960s, new breeds from IRRI carried the Green Revolution to the world's great rice basket, the broad arc from Bengal to Java to Korea. China developed its own high-yield rice, beginning in 1959. It came too late to mitigate the great famine of 1959 to 1961, which killed some 25 million to 30 million people—a political more than an ecological event in any case—but it did arrive in time to help Chinese agriculture weather the storm of the Cultural Revolution (1966–1976) (Dalrymple 1974:10–15, 73–75).

Borlaug saw the Green Revolution as humankind's best hope to feed rapidly growing populations, as perhaps it was. But its geographic spread suggests it had other attractions as well. The Green Revolution had little impact on sub-Saharan Africa, except for higher maize yields, notably in Zimbabwe.[5] It received its greatest support outside of Mexico on the frontier of the communist world from Turkey to Korea, and recommended itself as a means to blunt the appeal of socialist revolution, at its height in the 1960s. The rice programme in particular originated from American anxieties about the possible spread of Chinese communism after 1949. Meanwhile, socialist societies—China, Vietnam, and Cuba at least—embraced the idea of scientifically improved crops with equal vigor. In several of its manifestations, then, the Green Revolution was a child of the Cold War.

The Green Revolution also appealed keenly to most of the influential segments of society within Asian and Latin American countries. It promised to augment the incomes of landed elites and, where this was an issue, make land reform less urgent. To state bureaucracies it seemed to show a way to urban industrial society, and hence to wealth and power, without the risks of alternative paths. A more efficient agriculture, particularly an export-oriented one, could build up capital needed for industrialization and at the same time get labour off the land and into factories. Achieving this without the brutal costs of Soviet methods, or the noose of huge foreign debt, made excellent sense to the influential ministries of Mexico or Indonesia. Furthermore, the Green Revolution promised independence from American food aid, which recipients normally suspected as a political tool.[6] For all these reasons, both in the United States and in Latin America and Asia, the Green Revolution in the 1960s and 1970s was a technology package whose time had come.

Its impact was sudden, substantial, and like most revolutions, not quite what its instigators had in mind. Dozens of countries managed to keep food production ahead of population growth, mainly thanks to high-yield wheat and rice. By 1970 about 10 to 15 per cent of the Third World's wheat and rice area was under the new varieties. By 1983 the proportion was over half, and by 1991 three-quarters (Tolba and El-Kholy 1992: 296; WRI 1996: 226). In China, high-yield strains accounted for 95 per cent of rice and maize by 1990.

This dissemination of new breeds amounted to the largest and fastest set of crop transfers in world history. Bountiful yields became routine between 1960 and 1990, with effects more sudden and sizable than those of history's previous agricultural turning points. From the dawn of agriculture until the seventeenth century, yields (in Europe at least) increased only about 60 to 90 per cent. The first 'agricultural revolution' beginning in England around 1680, doubled English yields within 70 to 90 years. Most other European societies followed suit. Then between 1860 and 1910, yields doubled again—much less in the United States, more in Europe. Meanwhile, outside of Europe and the USA, yields and labour productivity stagnated or declined between 1800 and 1950, contributing to the prevailing inequalities in wealth and power (Bairoch 1989). With its basis in crop breeding and the transfer of successful strains, the Green Revolution merits comparison with the great historical crop introductions, such as the arrival of American food crops (maize, potato, cassava) in Eurasia and Africa after 1492, the importation of Southeast Asian plantains into tropical Africa, and the Arab introduction of citrus and sugarcane to the Mediterranean

Table 12.1: Yield History in 93 Developing Coutrise, Yield (kg/ha) 1961–1992

Crop	*1961–*	*1969–*	*1979–*	*1990–*	*Increase Factor*
1963	*1971*	*1981*	*1992*	*1962–1992*	
Wheat	868	1.153	1.637	2,364	2–7
Rice	1,818	2,218	2.653	3.459	1–9
Maize	1,157	1,456	1.958	2.531	2.2

Source: Adapted from WHI 1996: 226.

world after CE 900. Table 12.1 gives an impression of the phenomenal changes in crop yields since 1960 in the Third World.

As these yield figures show, the Green Revolution created the promised fields of plenty. It did much else besides. Ecologically it combined with mechanization to promote monoculture. Since farmers now had to purchase seed rather than use their own, and because they needed fertilizers and pesticides specific to a single crop, they saved money on inputs by buying in bulk for one crop. Monoculture, as explained earlier, invites pest problems. Often even the initially pest-resistant crops eventually proved vulnerable lo one or another infestation. Hence farmers turned to heavier and heavier doses of pesticides. This efficiently selected for resistant pests—as antibiotics did for bacteria.[7] Meanwhile, most of the pesticides missed their targets and ended up elsewhere, sometimes in water supplies, human tissues, and other awkward places. The WHO estimated in 1990 that pesticide poisoning killed about 20,000 people per year, mostly in cotton fields. Roughly a million people (as of 1985) suffered acute poisoning, two-thirds of them agricultural workers (ibid.: 296; see also Pimentel and Lehman 1993). The vast fertilizer requirements of the Green Revolution led to eutrophication of lakes and rivers. The necessary irrigation helped drive the huge dam-building programmes of China, India, Mexico, and elsewhere. The Green Revolution also altered the species and genetic diversity of agriculture: it extended the sway of rice, wheat, and maize, reducing the use of lesser crops not so responsive to nitrogen-and water-rich diets: and it vastly reduced the varieties of rice, wheat, and maize in wide use. Before the Green Revolution, farmers raised thousands of strains of wheat around the world. After it, they increasingly used only a few. In this respect, the Green Revolution was a gamble that scientific agriculture could protect a few high-yield strains from pests and diseases. By and large it has, by staying one step ahead of the evolution of pests, as antibiotics did with pathogens.[8]

It was also a gamble that oil and water would remain cheap enough to satisfy the energy gluttony and bottomless thirst of the new agriculture. So far, this too has worked, within limits.[9]

The social consequences of the Green Revolution brought more surprises. In many settings it did not defuse agrarian tensions. In Mexico and the Indian Punjab, for example, the Green Revolution strongly favoured farmers with reliable access to credit and water. Some of the less fortunate drifted to the cities, some went to work for the more successful, others went to the United States or the Persian Gulf to work for wages—in cases to accumulate enough capital to become prosperous peasants—Green Revolution kulaks—themselves. As a rule, though not without exceptions, the Green Revolution promoted income inequality among farmers. Where alternative employment for the losers was hard to find, as in Punjab or highland Ethiopia, social frictions intensified into overt class and ethnic or religious conflict. A sampling of the literature suggest that the social effects proved more favourable in land raisings rice than those with wheat.[10]

The Green Revolution, like farm mechanization, selected winners internationally as well as ecologically and socially. South Korea, China, India, and to a lesser extent Mexico improved their agricultural balance of payments, reduced or eliminated food dependence, and, whatever the ecological or social costs, improved their international economic and political position. Countries that could not create favourable conditions for the Green Revolution—those with too little water or underdeveloped credit markets—suffered in comparison. Broadly speaking, this meant sub-Saharan Africa sank in the scales against Asia and Latin America as a Cold War tool of the West—which in part it was—the Green Revolution served its purpose, although high-yield rice strengthened communist China as much as it did Asia's island fringe, which America relied upon to contain China.

The Green Revolution did something—but not much—to empower Latin America and tropical Asia vis-a-vis the West and Japan. It helped in the industrialization drives of Taiwan, South Korea, Indonesia and the other 'Asian tigers'. It made India a food exporter. But while the Green Revolution made Third-World agriculture more land-and labour-efficient, it could not match the productivity increases ongoing in the West and Japan. In 1950, agriculture in the West was seven times more labour-efficient than in the Third World; in 1985, 36 times more—and about 36 times more prosperous. The Green Revolution did not engineer income redistribution toward

Third World farmers. Nor did it achieve food independence except for a few countries. Until, 1981 the Third World had long been a net exporter of food; after 1981 it was a net importer (Bairoch 1989: 346).

These facts derive from the continuing agricultural revolution in the West and Japan from which the Green Revolution was an offshoot; and from agricultural and trade policy. Take Britain, for example, a major food importer since the repeal of the Corn Laws in 1846. British agricultural yields stagnated between 1890 and 1940. Subsidies and protection began in the 1930s. Meanwhile, the biological, chemical, and mechanical transformations of modern agriculture took hold, and yields rose beginning in 1942. The difficult food situation in Britain during World War II and the immediate post-War years predisposed all governments, Labour and Conservative, to favour agricultural subsidies, firmly buttressed in 1947 and to pursue higher yields through scientific agriculture. Yields doubled or tripled by the 1980s. To the dismay of devotees of the principle of comparative advantage, Britain, which grew 30 per cent of its grain in 1936, managed self-sufficiency in 1986.[11] Similar miracles occurred in the fields of much of Europe, Japan, Australia, New Zealand, and North America after 1945.[12] The Soviet Union partly missed out because modern genetics rankled the socialist sensibilities of Stalin and Khrushchev, delaying progress in plant breeding until the mid-1960s. Before 1960 the USSR partook of mechanization and irrigation, but only after 1965 did it undertake conversion to the doctrine of genetic manipulation and heavy use of nitrogen. Thus the total geopolitical effect of modern changes in agriculture improved the relative position of the West and Japan slightly, that of China, the Asian tigers (South Korea, Taiwan, Malaysia), and Latin America even more slightly, while contributing to the relative decline of Soviet status, and to the weakness of Africa.[13]

Conclusion

The general transformation of farming after 1940, of which mechanization and the Green Revolution were parts, both shaped the twentieth century and reflected its dominant trends. It was energy- and knowledge-intensive. It replaced simpler systems with more complex ones, involving distant inputs and multiple social and economic linkages. It reduced family and regional autonomy, enmeshing farmers in a world of banks, seed banks, plant genetics, fertilizer manufacturers, extension agents, and water bureaucrats. It transplanted what worked in the West and Japan to other societies. It sought to harness nature tightly, to make it perform to the utmost, to make it maximally subservient to humankind or at least some subset thereof. And it sharply increased output, making us dependent upon its perpetuation. As of 1996, to feed ourselves without these changes, we would have needed to find additional prime farmland equal in area to North America.[14]

Lacking such a spare continent, the human race ended the twentieth century in a rigid and uneasy bond with modern agriculture. Our recast agro-ecosystems depended on social and international stability to safeguard required flows of inputs. Our social and political systems required the perpetuation of these agroecosystems.

The modem agricultural revolution was nearly as important as the new regime in human-microbial relations in shaping the twentieth century. Both fundamentally affected the well-being, health, and security of life for billions of people. Both helped govern the ongoing redistributions of power and wealth among classes and nations. Both represented a drift toward ever-greater complexity—and potential vulnerability to disruption—in the systems that underpin modern life.

The fact that we are not more often food for microbes depends on the precarious balances of modern public health; that we in turn have as much to eat as we do (questions of distribution aside), depends on the no less precarious balances of modern agriculture. Though you drive out nature with a pitchfork, yet it will always return,' So thought the Roman poet Horace.'[15] Is his wisdom now out of date?

Notes

1. Italian crop breeders also enjoyed early success, using Japanese varieties from 1912: by 1932 a quarter of Italian wheat—Mostly in the north— was early-ripening breeds derived from crosses with Japanese wheat. These Italian wheats by the 1970s were in wide use in the Mediterranean world. (Dalrymple 1974: 10–11)
2. In a double-cross, four varieties are combined in two 'generations,' selecting for the most desirable characteristics.

3. Wallace (1888–1965) was a farmer, publisher of an agricultural journal and son of Warren Harding's Secretary of Agriculture. Wallace became FERS Vice President in 1941, but was replaced by Truman four years later. He fell out with Truman, partly over foreign policy, and subsequently ran for the Presidency several times as leader of the Progressive Party.
4. Jennings 1988 deals with the politics of the Rockefeller initiative. Apparently Henry Wallace and the top managers of the foundation hoped to support the president elected in 1940, Avila Camacho, from whom they hoped for some compromise with respect to American property (including that of Standard Oil) nationalized by the previous president, Lizard Cardenas. Wheat was then a minor crop in Mexico. See also Fitzgerald (1986).
5. Hybrid maize research began in Southern Rhodesia (now Zimbabwe) in 1930. A variety (SR-52) released in 1947 proved successful on the commercial farms (mainly white-owned) after 1950. SB-52 raised yields in southern Africa by about 51 per cent but the expensive inputs limited its use among poorer peasants. No other Green revolution crop had significant impact in sub-Saharan Africa, see Jahnke *et al*. (1987), and also Low (1985).
6. This occurred especially after the passage in 1964 of U.S. Public which 480 which connected food aid to improving attitudes toward the United States.
7. Resistant pest species increased about four-fold between 1955 and 1988 (estimated from Tolba and El-Kholy 1992:295).
8. A partial exception camp in 1970 when a dingus especially well adapted to U.S. corn destroyed 15 per cent of the harvest, prompting farmers to vary the genetic profile of their seed in 1971(Mangelsdorf 1974:213).
9. See Freeman (1993) for the limits as seen by a booster (a former U.S. Secretary of Agriculture). Pimentel and Heichel (1991) show that in energy terms high-yield crops are about 25 per cent as efficient as hand-and-hoe agriculture and half as efficient as ox-and-plow farming. Indeed, modern U.S. farming burns far more calories than it produces when one factors in the energy requirements of making fertilizer.
10. Critiques of the social implications of the Green Revolution are numerous. See Shiva 1991; Thandi 1994 (on Punjab); Hazell and Ramasamy 1991 (on Tamil Nadu, where things went well); Allaudin and Tisdell 1991 (on Bangladesh, where they did not); Simonian 1995:170–72 and Sonnenfield 1992 (on Mexico). On income distribution specifically, see Sharma and Poleman 1993 and David and Otsuka 1994. Bezuneh and Mabbs-Zeno 1984 write on Ethopia's Green Revolution and its impetus to unrest and political revolution in the 1970s.
11. Blaxter and Robertson (1995). The hallowed principle of comparative advantage states that countries maximize their income by producing only

what they produce most efficiently and trading for all other goods. This Britain resolutely did not preferring food security to income maximization.

12. See Cochrame (1993); Hayami and Yamada (1991). In the century 1880–1985, Japanese agriculture increased labour productivity 16-fold despite the requirements of rice. Land productivity (yields) improved by a factor of 4.4 (Hayami and Yamada 1991:253–54).
13. In addition to the works cited above, I consulted Burmeister (1990), and Freeman (1993).
14. This figure comes from Dennis Avery, cited in the *Economist*, 16 July 1996: 23. Other solutions include, of course, more equitable distribution of food and an alternative technical means of making food production more land efficient.
15. From Epistles 10:24: 'Naturam expellas furca tamen usque recurret.'

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