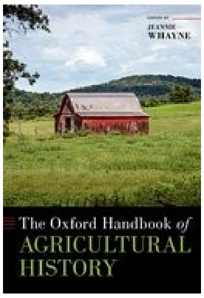

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CHAPTER

14 Corn

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Abstract

Corn (or maize) is an exemplary commodity of far-reaching changes to capitalist agriculture. After briefly describing how corn traveled from Mesoamerica to Europe and Africa during the colonial period, this chapter describes several key processes through which corn became a ubiquitous, industrial "flex" crop. Drawing on agrarian political economy and food regime approaches, the chapter highlights several changes in government policies and technologies in the United States and Mexico and argues that corn played a pivotal role in the ability of capital to overcome natural barriers to accumulation and commodification found in agriculture. The chapter ends by suggesting that in addition to its pivotal role in capitalist agriculture and the emergence of a global food regime dominated by neoliberalism, corn has also been an important focus for anti-GMO activist networks that challenge the global food system.

Keywords: maize, corn, capitalism, United States, Mexico, hybrids, flex crop, GMOs, food regimes

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As the quintessential Indigenous crop of the Americas and fundamental to far-reaching changes to agriculture under capitalism, corn has helped shape human societies. Agrarian political economy and food regime approaches to food and agriculture permit the analysis of several key processes through which corn or maize (used interchangeably here) went from being a staple crop of the Americas, to a global commodity and a ubiquitous, industrial "flex" crop found in products ranging from ketchup to ethanol. The physical and physiological characteristics of the corn plant, and its adaptability and transportability, are instrumental factors in why humans took up maize cultivation and how it became a global staple.

Certain crops, like corn, have always had uses beyond food: for centuries, maize has provided not just a key food staple, but it was used for making alcohol and as animal feed, in addition to a plethora of other uses for the various parts of the plant, such as leaves for *tamal* wrappers or in decorations and cobs for fuel. During the twentieth century, these uses multiplied as corn became an ingredient in processed foods, ethanol, sweeteners, and bioplastics. In the twenty-first century, however, there has been a global trend toward multipurpose agriculture or "flex crops," and corn has played a central role in this shift. Corn is the most established, and among the most significant, flex crops due to the physiological and physical characteristics of the plant, and its early and pivotal role in plant breeding science, industrial agriculture, and agricultural biotechnology.

The food regime approach, informed by agrarian political economy, provides a helpful framework for understanding the significance of corn for capitalist, industrial, and later, multipurpose agriculture. The food regime approach historicizes the role of food in an emerging global food order and focuses our attention on policies and practices (such as international trade, food aid, regulation and labels, and agricultural subsidies, among others) related to food production, provisioning, and consumption. Agrarian political economy asks questions about the ways in which capitalism unevenly inserts itself in agriculture, how agriculture contributes to capitalist accumulation and industrialization, and how these processes shape social relations in different places. Since agriculture entails harnessing biological processes (e.g., through
p. 252 photosynthesis and cultivation and ↳ gestation cycles), it poses "natural" obstacles to capitalist development and accumulation; however, in the twentieth and twenty-first centuries agri-food capital has successfully sought ways to overcome some of these challenges, particularly, through mechanization and the production of industrial inputs such as synthetic fertilizers and pesticides.

Maize is an important part of the story of the industrialization of agriculture and how capital overcame natural barriers to accumulation. David Goodman, Bernardo Sorj, and David Wilkinson (1987) delineate two processes that surmount some of the natural barriers to capitalist accumulation in agriculture—what they term "appropriationism" and "substitutionism." What these processes do is separate agricultural production into specialized sectors, industrialize them, and relink them through national and international supply chains. When an aspect of farm production is undermined, converted into an industrial process, and reincorporated back into the farm as an input, it is referred to as a process of appropriationism.[1] For example, appropriationism refers to the replacement of manual labor by machinery or of manure with synthetic fertilizer.

Substitutionism refers to a situation when an agricultural end product is transformed into standardized, homogenized inputs by industrial processing, such as flour milling, sugar refining, and oilseed pressing, or when the end product is replaced with a new end product made from less expensive industrial raw materials, such as margarine as a replacement for butter. These transformations in farming and agriculture—some of which began in the late nineteenth century and took off with the industrialization of farming in the mid-twentieth century—were uneven, but, in general terms, they entailed a shift toward more specialized production around particular commodities, more capital-intensive farming, and created economic conditions much less favorable to small family farms. In effect, what was previously an integrated system of energy and nutrient recycling controlled by farmers became a process of buying and selling industrial inputs and outputs, reducing the control farmers had in the process, while leveraging the influence of agribusiness corporations.[2]

From Mesoamerica to the Colonial World

> "Enlightened [colonial] elites used corn in this sense: as a contemptible object subject to discrimination. Corn carried the stigma of being alien, strange, poor. The wealthy judged corn and declared it to be guilty. The poor, on the contrary, opened their doors to it, embraced it, adopted it.... Corn was an adventurer, a settler of new lands, one of those that helped fashion the modern world from the distant sidelines."
>
> —Arturo Warman, *Corn and Capitalism* (1988), xiii

Food and agriculture were central to colonial projects in the Americas, which entailed attempts to eradicate
p. 253 Indigenous peoples and to "civilize" them into European customs, ↳ including dietary and agricultural practices, while also keeping them separate and inferior. European explorers and settler colonists were often suspicious of Indigenous foods. Sixteenth-century Europeans argued that the Indigenous diet was dangerous for Europeans, despite the fact that most explorers, fur traders, and early settlers reported eating local staples such as maize.[3]

Mexican anthropologist Arturo Warman traces the history of maize from Mesoamerica to its emergence as a global staple crop. He demonstrates that corn was a key player in the expansion of colonialism and the capitalist world system, and that by following the crop's history of adoption around the world, we have insight into how local farmers, and their environments, fared under various colonial and capitalist relations. Although corn was often held in disdain in colonial narratives, it became a staple crop of colonial diets and of the Atlantic slave trade, because corn is easily and efficiently stored for food and feed. In other words, thanks to its botanical characteristics, maize not only helped transform Mesoamerican civilizations and societies, but helped "fashion the modern world."

Corn is a particularly flexible plant in the sense that it can be grown in a vast array of environments. It can be eaten as a vegetable by those who grow it or dried and stored by farmers to be used for animal feed or to be prepared as foods like tortillas, polenta, porridge, and beverages. This ability to grow in an array of environments and the ease with which corn can be stored and transported meant that as maize traveled from the Americas to Europe, Asia, Africa, India, and elsewhere, it was often recognized by small-scale farmers for its adaptability, and in some cases as a means to remain relatively self-sufficient. Corn became one of the world's most important staple food crops, alongside wheat and rice. Today, corn is the most cultivated cereal grain worldwide, grown on every continent except Antarctica. It is also the most important cereal grain used for food in Latin America and Africa, where white varieties of corn are preferred for human consumption. In 2022, the world produced 1.2 billon metric tons of corn.[4]

Zea mays comes in five phenotypes—sweet, pop, floury, dent, and flint—and is a member of the grass family, but unlike other grasses, the maize plant relies on humans to remove the tightly covered kernels from the husk and plant them. In other words, maize is a plant that coevolved with humans and can be considered a "companion species." For this reason, Warman refers to corn as "our plant kin" explaining that "people and corn depend upon each other in order to subsist and survive as a species" (1988, 27).

The biological origins of maize were for a long time a mystery, but we now know it was domesticated from a single ancestor, a wild grass called teosinte, nine thousand years ago in south-central Mexico. Both the Maya and Aztec civilizations, among other Mesoamerican groups, cultivated the descendants of that ancestor and became "people of corn" developing cultural practices, myths, and legends about the crop. In the seventeenth century, Carl Linnaeus's work in taxonomy included using a binomial nomenclature for biological organisms, and he redundantly added *Zea*, the Greek word for "life-giving," to "mays," the Latinized version of *mahiz*, which in Taino meant "life-giving seed."[5] The word *Zea* is from ancient Greek

p. 254 and refers to grains and cereals in ↳ general, and the English referred to maize as "Indian corn" because corn was the generic term for cereal grains.

In the Americas, maize was traditionally intercropped with squash and beans, both of which are plants that do not compete with corn for sunlight. Squash lowers the evaporation of ground moisture around the corn and impedes the growth of weeds with its foliage, while beans grow up the stalk of the maize plant and, like all legumes, help take nitrogen from the air, where it is abundant, and make it available to the plant. The "three sisters," as these companion crops are called among Indigenous nations of North America, or the "milpa" in Latin America (which refers to the cornfield plus these two other plants), are also nutritional complements.

In addition to the nutritional complementarity of the companion crops, the technique of nixtamalization developed in Mesoamerica, and practiced by various Indigenous peoples of the Americas, also enhances the nutritional content of maize. This technique entails soaking and cooking corn kernels in water with alkali (with mineral lime, or in some places, wood ash lye), and after rinsing, the kernels are hulled, making them easier to grind and make masa (or corn dough). The word "nixtamal" has Nahuatl origins, combining the term for ashes (*nextli*) with tamal (*tamalli*). Nixtamalization is still widely practiced in parts of Mexico and Central America and is also used in the industrial production of some corn-based foods. Nixtamalization increases the calcium content of corn and makes niacin available for absorption when eaten, helping to prevent pellagra, a disease caused by severe niacin deficiency. When maize traveled from the Americas to Europe, Asia, and Africa, it was introduced without the technique of nixtamalization, making those populations reliant on corn diets susceptible to pellagra. Unfortunately, because the technique of nixtamalization did not accompany corn on its global travels, as cornmeal became "the poor man's staple everywhere—*mamaliga* in Romania, *puliszka* in Hungary, *sofki* in Ghana, *mealies* in South Africa, *fungie* in Zaire—it lost an important source of nourishment."[6]

Spanish ships brought maize from the Caribbean to Seville, and then the crop made its way through Italy, Egypt, and Africa. The first reference to maize in Africa was by an anonymous Portuguese ship pilot who described its cultivation on the Cape Verde islands between 1535 and 1550.[7] Corn cultivation also made it to China via the Portuguese, but its cultivation was quite limited until 1700. Maize had become one of China's major crops by the early twentieth century, and during the twenty-first century, for the first time in Chinese history, corn production surpassed that of rice.[8]

In West Africa, flint maize adapted well where sorghums and millets had been cultivated, and corn was grown because its quick maturity let some of the varieties escape drought; but floury maize became more popular than flint corn with its hard starch and lower yields. Outside of West Africa, corn was adopted as a novelty or niche crop. For example, in Ethiopia it was not until the twentieth century that corn went from a garden vegetable to a field crop.[9] In colonial southern Africa, maize offered clear advantages in yield and labor requirements over the African cereal crops of sorghum and millets; it had higher yields and a shorter growing cycle than sorghum. Corn began to replace these African subsistence crops among Black farmers p. 255 who embraced planting maize ↳ earlier than white settlers. Farmers cultivated floury and white flint maize, which was preferred for food. However, when the American white dents arrived—which had higher yields than flint corn and softer starch making it more suitable to mechanized mills—white farmers began to treat maize as an important cereal crop. In *Maize and Grace* (2005), James McCann explains that as American dent corn was adopted and cultivated in southern Africa it was treated as a commodity grain and was part of a larger shift toward industrial and export agriculture in the region. American white dent corn provided the economic base for the growth of settlers' rule in southern Africa.[10]

The story of how American maize became both an African subsistence crop and an industrial cash crop illustrates key changes in the international food system or "regime." The food regime approach explores connections between capitalist accumulation and the international relations of food production and consumption. The first international food regime occurred from about 1870 to the 1920s, the era of imperialism, when colonial policies consolidated specialized export zones: while tropical imports were produced to export to European consumers, settler colonists focused on farming wheat in places like Canada, Australia, and Argentina. Settler colonies helped resolve the social and economic difficulties posed by land dispossession when peasants were displaced from their land: it enabled some to leave and become settler colonialists and, in the process, provided food for the empire.[11] By 1930, maize surpassed wheat in colonial Africa as the most important cash crop and sorghum as the major food crop. And yet, despite maize's growing importance in colonial Africa, agricultural research focused on cash crops like coffee and cotton, cocoa, and other crops that linked African economies to the emerging world commodity markets. Investments in African maize varietal improvement largely focused on high yield as the most important trait to advance. Unlike most elsewhere in the world, the vast majority of the maize grown in Africa is white maize consumed directly by humans instead of being fed to livestock or used as an input in industrial processing.[12]

At the turn of the twenty-first century, countries of the Global South—that is, low- and middle-income countries, the majority of which are former colonies—that once grew their own maize as a key food staple are dependent on corn imports, as a result of market-oriented neoliberal policies. Although maize is Africa's most important crop, grown both in large industrial mono-cropped fields, as well as by small-scale subsistence farmers, the continent has become a net importer of the crop.[13] Notably, Mexico, too, a center of domestication and biological diversity for maize, now imports one-third of its corn from the United States. Most of the world's maize that is used for direct human consumption is consumed in Africa and Latin America. White corn is preferred in countries like Mexico and Guatemala for human consumption in order to make tortillas and other corn-based foods; however, US imports tend to be yellow, genetically engineered varieties used for feed and industrially processed foods.

World War I interrupted trade, and a new regime stabilized in the years following World War II. The second food regime, centered on US hegemony, was driven by industrial agriculture, development policies and banks, and a shift in US policy and trade relations. In the post–World War II period, for example, the US p. 256 Public Law 480 created ↳ international food aid through which the United States sent subsidized food and agricultural products to other nations. Food consumption patterns shifted in many places with the industrialization of agriculture and the move toward meat-heavy diets.

While the history of corn's migration around the globe points to the diverse ways it was adopted by farmers in different locations and contributed to an increased number of varieties of corn through crossing and free pollination, in contrast, the popularity of hybrid corn in the United States reduced the number of corn varieties grown in modernized and industrial agriculture.[14]

From Staple to Industrial Crop

> "With the advent of the F-1 hybrid, a technology with the power to remake nature in the image of capitalism, *Zea mays* entered the industrial age and, in time, it brought the whole American food chain with it."
>
> —Michael Pollan, *The Omnivore's Dilemma* (2006), 31

Corn was the first crop to be transformed into an industrialized commodity in the nineteenth century. By the 1950s, industrial commodity corn had changed farming in North America. Several technologies were fundamental to this shift toward modernized, industrial corn agriculture, notably the John Deere steel plow of the late 1830s, grain elevators, the tractor of the 1920s, advances in milling, the technique of hybridization, synthetic fertilizer, and the expansion of the railroad system. These technological advances were often supported by government policies, and capital pursued both technological and social avenues to overcome barriers to accumulation. Industrial corn became an American success story, remaking the landscape of the American Midwest with high-yielding hybrids increasingly cultivated on monocropped farms using industrial inputs.

The hybridization of corn was a turning point for capitalist accumulation in agriculture and entailed a process of appropriation.[15] In the nineteenth century, the US government undertook germplasm collection and research and distributed high-quality seed without fee to farmers. Varietal development was a process of simple selection that could be undertaken by farmers into the twentieth century; however, with the increased knowledge of hereditary differences in the early twentieth century, plant breeding shifted from the collection of sought-after plant varieties to the collection of plant varieties with sought-after traits. This began to pay off in the 1930s when hybrid corn became commercially available and US corn yields increased.

Although maize is a naturally hybridizing plant, a maize "hybrid" refers to a variety that results from the crossing of two different varieties, each of which has first been inbred to the point of being genetically uniform. The first generation of a hybrid variety (called F-1 by plant breeders) has an increased yield or hybrid vigor. Unlike open-pollinated varieties developed by scientific plant breeders, though, the second p. 257 generation of hybrid corn (F-2)—that is, the generation that appears after the seed is ↳ saved and replanted—exhibits a considerable reduction in yield. Hybrid corn overcame what sociologist Jack Kloppenburg (1988) has called the "biological barrier" to commodification because farmers interested in maintaining good yields must purchase hybrid seed for each planting. By the 1940s, hybrid corn was grown throughout most of the Corn Belt, a decade after it had first been introduced.[16] Bred for thicker stalks and stronger root systems to remain standing, hybrids withstand mechanical harvesting and have yields higher than open-pollinated varieties largely because they can be planted closer together. Hybrid corn was a remarkable innovation, but one of its downsides for farmers is what makes it an early example of appropriationism; in other words, an aspect of the agricultural production process, in this case the reproduction of seed, was no longer in the hands of the farming household or community but produced offsite and reincorporated back into the farm as a purchased input. Hybrid corn also entailed, as Deborah Fitzgerald (1993) has shown, a process of de-skilling, as it "effectively locked farmers out from an understanding of their own operations without the aid of experts."[17] Not surprisingly, hybrid corn played a key role in the establishment and success of seed companies in the United States in the early twentieth century aided by policies that prioritized hybrids over open-pollinated varieties, which could be replanted.

In the US Corn Belt, hybrid corn yields improved significantly with the invention and commercial availability of chemical fertilizers in the 1950s. While average yields were 22 bushels per acre in the 1930s, by the 1970s, yields increased to 95 bushels. Today US yields are close to 200 bushels per acre. The average yield in the Global North (or higher-income countries) is 8 tons per hectare and in Global South it is less than 3.[18] Synthetic nitrogen meant that farmers no longer had to rotate their crops with legumes, which add nitrogen to the soil. By 1965, more than 95 percent of US corn acreage was planted with hybrids, largely relying on synthetic nitrogen.[19] The production of synthetic nitrogen requires fossil fuels. From a biological perspective, the reliance on synthetic fertilizer has transformed corn agriculture, together with the widespread adoption of the tractor, from a process of capturing sunlight and turning it into food "to converting fossil fuels into food."[20] Every acre of industrially produced corn requires at least 50 gallons of oil.[21] The ecological costs of producing industrial corn entails not only increased fossil fuel consumption, but nitrogen runoff from the synthetic fertilizer applied to farm fields that makes its way into water supplies, among other issues.

In Mexico, during the 1940s, the Rockefeller Foundation's research and training project, named the Mexican Agricultural Program (MAP), was set up in order to raise the productivity of maize and wheat, among other crops, in the hopes of alleviating hunger, raising the nutritional levels of the average diet, and reducing Mexican dependency on basic food imports. The Foundation worked in collaboration with the

Mexican Ministry of Agriculture and Animal Husbandry (now SADER) and the Office of Special Services, a semiautonomous office of the ministry. As a result of this project, Mexico was the first developing nation to undergo an agricultural Green Revolution, which took place primarily in the country's irrigated regions of the north. When the project ended in the 1960s, Mexican wheat yields were among the highest in Latin America—and became a model for the development of semi-dwarf, high-yield, disease-resistant wheat varieties p. 258 in India and elsewhere—but maize yields remained low.[22] This Green Revolution favored wheat over corn and benefited larger, commercial farmers over more subsistence-focused, smaller-scale peasant farmers because the project's varieties often required irrigation, synthetic fertilizers, and other commercial inputs.

The project's varieties helped transform the uncultivated areas of Mexico's north and northwest states into wheat-producing farmland. The government financed roads and irrigation works, agricultural banks and credit, and guaranteed wheat prices for large-scale farmers. These policies and subsidies contributed to the postwar industrialization of Mexico, and in some areas, maize was displaced for more remunerative crops. Small landholdings became sources of cheap labor for expanding industries and agro-exporters. Mexico would soon need to import corn again—as had happened during a food crisis in the late 1930s, when the supply of cereal grains and beans became a serious problem due to crop shortfalls and transportation problems.[23]

As more profitable crops replaced maize in the north of Mexico and the government imported yellow corn from the United States to supply urban consumers, corn became a nostalgic symbol of middle-class nationalism. In his history of Mexican cuisine, Jeffrey Pilcher (1998) demonstrates that during the 1940s, a period marked by rapid urbanization and industrialization, import substitution, and the "Mexican Miracle" of economic growth, corn-based foods that had formerly been considered poor, nutritionally deficient, and backward were appropriated by the growing middle and urban classes as "authentically" Mexican. In the same period, but increasingly from the 1960s, the diet of the poor incorporated sugar and fat, especially in the form of soft drinks and processed foods.[24] Meat consumption also rose among wealthier Mexicans, resulting in an increase in sorghum cultivation for cattle feed during this period.[25] The cultivation of sorghum, and later corn, for animal feed was increasingly linked to industry, both national and international. The interest and demand for artisanal, "authentic" tortillas among middle-class Mexicans (and North Americans) would again increase following the neoliberal reforms of the 1980s, and the North American Trade Agreement (NAFTA) of the mid-1990s, when Mexico's reliance on US corn imports grew, and these imports were increasingly genetically engineered varieties.

From Livestock-Feed and HFCS to Flex Crop

> "Corn's triumph is the direct result of its overproduction, and that has been a disaster for the people who grow it."
>
> —Pollan, *The Omnivore's Dilemma* (2006), 118.

In 1970, approximately 85 percent of US corn was planted with hybrid varieties that had cytoplasmic male sterility (CMS-T), which was popular because it eliminated the need for the labor-intensive process of de-tasseling. Unfortunately, CMS-T varieties were also susceptible to the southern corn leaf blight, which became an epidemic that same year. Because fields were sown with the same crop (monocropped) and with varieties that p. 259 shared a genetic component susceptible to the blight, 15 percent of the total US corn crop was destroyed, hitting the Corn Belt the hardest. The impact of the blight highlights the need to maintain a degree of genetic variation in major crops when planted, and also in the genetic materials available *in situ* and *ex situ* for breeding purposes.

Corn harvests recovered in 1971—thanks to better weather, the reduced use of CMS-T varieties, and the employment of students to de-tassel the female plants by hand in the corn seed fields—and in the fall of 1972, Russia purchased 30 million tons of US corn after experiencing a huge shortfall. This helped boost the price of US corn, temporarily, and enticed farmers to plant the crop or expand the land devoted to it. In 1973, the US Farm Bill started to pay farmers directly rather than using support prices and government grain prices. This was a key policy shift. As Michael Pollan explains, the Farm Bill "removed the floor under the price of grain. Instead of keeping corn out of a falling market, as the old loan programs and federal granary had done, the new subsidies encouraged farmers to sell their corn at any price, since the government made up the difference."[26] Most subsequent government Farm Bills, however, have lowered the price of corn. Facing corn prices lower than the cost of production, US farmers looked for ways to raise yields and grow more corn in order to keep up with their expenses, but many faced rising debt and bankruptcy.

The increased yields with corn hybrids and synthetic fertilizer in the United States also facilitated the expansion of large feedlot operations where animals, in more confined spaces, are fed diets of corn. For cattle, this change of diet from grass requires the use of antibiotics for the animals to remain healthy. When the 1973 Farm Bill allowed corn prices to fall below cost of production, it became profitable to feed inexpensive corn to cattle, pork, and chicken. The most popular variety of corn for feed and industrial processing is yellow dent "field corn," which is different from the sweet corn consumers eat as a vegetable. This overproduction of corn has rippled out to many aspects of agriculture and the food chain in the United States and abroad: the United States exports up to 20 percent of its corn harvest to places like Mexico.[27]

This second food regime was also characterized by agri-food capital investments in increasingly complex forms of appropriationism and substitutionism including the replacement of traditional foods produced in the tropics like cane sugar and peanut oil with derivatives that could be produced in more temperate climates such as soybean oil and high-fructose corn syrup (HFCS). The replacement of cane sugar with HFCS and gasoline with ethanol-blended "gasohol" are both part of the process through which capital overcomes obstacles to accumulation in agriculture.[28]

The market for HFCS grew rapidly in the 1970s after a breakthrough in the wet milling process with the use of enzymes, shortening the time needed. Wet mills convert corn into the basic component parts of processed foods and are thus a significant technology in the industrial food chain. In the wet milling process, the corn kernel is separated into three main parts: the hull or outer skin, the germ, which contains most of the oil, and the endosperm for gluten and starch. In the 1840s, wet milling was used to make corn starch and by the 1860s, acids were included in the milling process to produce glucose from corn starch, p. 260 enabling corn syrup to hit the market. Corn syrup was the main product of ↳ wet milling processing until Japanese chemists discovered that using an enzyme instead of acid transforms glucose into the even sweeter fructose molecule, thus paving the way for the rise of HFCS.

Large buyers of corn, like Cargill and Archer Daniels Midland (ADM), began exercising influence on the direction of US policy in the 1980s, which often reflected their interests above that of farmers.[29] The price of sugar rose after the US government increased support for domestic sugar farmers and extended an import quota on sugar thanks to the lobbying efforts of ADM, among others. In 1984, both Pepsi and Coca-Cola announced they would no longer use sugar in their soft drinks, replacing sugar with HFCS. The consumption of the sweetener soared in the United States, and other countries followed the uptake in consumption, most notably in Canada, Mexico, Hungary, Slovakia, Bulgaria, Belgium, Argentina, Korea, and Japan. Growing health concerns about this new sweetener followed.

As gas prices rose in the 1970s and there was increasing concern over foreign oil dependency, ADM hoped that the same wet mills the company used for HFCS could be used to produce ethanol in the summer when soft drink sales were lower.[30] At the time, ADM was producing one-third of the HFCS in the United States and lobbied the US government to secure some protections for the sector, like a tax exemption and a tariff imposed on Brazilian ethanol. Alcohol blends from the fermentation of plant materials for transportation fuel gained popularity in the nineteenth century, but it was not until the 1970s that a food/fuel complex emerged.[31] The first generation of biofuels converted the sugar and oils from food and feed crops, including corn, into fuel. The market for ethanol took off at the turn of the twenty-first century alongside a decrease in the per capita intake of HFCS in the United States.

The boom in biofuels during the 2000s, as an alternative to fossil fuels, was a key moment in the transition toward "flex crops," or multipurpose agriculture. Between 2000 and 2016, annual global biofuel production surged from 18 billion to 135 billion liters, primarily using maize, sugar cane, and oil palm.[32] Corn is the among the most established and significant flex crops, alongside soybean, sugar cane, and oil palm, in the global expansion of multipurpose agriculture.

Championed for their versatility, flex crops can be used for food, fuel, and as an industrial material. Crops are flex crops in two ways: first, the same crop can be used for different purposes and in making different products; and second, they have the capacity (or perceived capacity) in different and changing economic and technological conditions to be redirected or substituted from one use to another. Flex crops have a greater capacity than other crops to replace farm-based produce with industrially produced substitutes (the process of substitutionism) and they are, or are thought to be, more easily substituted into gaps in a supply chain.[33]

Current research on flex crops shows that the benefits of this boom are primarily accrued by the agro-industries that control the value chains and seldom by the farmers who grow the crops.[34] Flex crops appeal to financial investors because investment in such crops is similar to having a diversified portfolio; it helps reduce uncertainty and stabilize or increase profits.[35] Unfortunately, corn is one of the more energy-intensive p. 261 ↳ crops—if not the most inefficient—from which to produce biofuels, and when corn is channeled away from the food chain into biofuel production, it is also disruptive to global food prices.[36] Due to the concern and controversy around whether first-generation biofuels adversely affect the food supply and raise the price of food, a second generation of biofuel technologies that do not rely on food crops for biofuel feedstock, or only rely on the non-edible parts of food crops, are in development.

The third international food regime that began to take shape in the late twentieth century was characterized not only by the establishment of a food/fuel complex, but also by the rise of genetic engineering as a key technology for capitalist agriculture and by changes in regulation in relation to this technology. Genetically engineered corn was first commercially available in 1996 and constitutes over 90 percent of all corn grown in the United States.

GMOs and the Neoliberal Food Regime

> "Without corn there is no country" (*sin maiz, no hay país*).
>
> —Slogan from Mexico of the anti-GM corn network In Defense of Maize (2001)

The 1980s brought a wave of structural adjustment policies to countries facing economic crisis. These policies, informed by a neoliberal agenda, included austerity measures and widespread cuts to public services, as well as agricultural and food price supports and subsidies as conditions for the loans provided by the World Bank and International Monetary Fund (IMF). Mexico was the first country to implement structural adjustment policies as part of its loan package with the IMF in an effort to refinance its foreign debt. In addition to cuts to subsidies and price supports, these policies promoted liberalized trade agreements, often via the World Trade Organization.

In general terms, the emergent food regime is characterized by neoliberal policies and a further consolidation of corporate power in the food and agriculture sectors. This period also witnessed a rise in nontraditional food exports from the Global South such as fruits, vegetables, and meat, the expansion of supermarket chains, the financialization of markets, and the rise of flex crops. While countries in the Global North like the United States continued to export subsidized grain, agricultural subsidies were cut in the Global South. Together these policies and processes have pushed small-scale farmers and agricultural laborers into a casual global workforce.

After a drop in oil prices, an economic crisis hit Mexico in the early 1980s and there were peso devaluations, inflation, and debt renegotiations. The country brought its policies in line with the structural adjustment agendas of the World Bank and the IMF implementing cuts to rural subsidies and counter-agrarian reform policies (such as those which enable communal landholders to sell land). Agribusinesses expanded operations in Mexico, increasing exports of fruits and vegetables to Canada and the United States largely
p. 262 based on conventional, capital-intensive agriculture. As part of the project ↳ to liberalize trade, NAFTA went into effect in 1994 and Mexican imports of US corn dramatically increased. It is a bitter irony of the neoliberal food regime that countries of the Global South, like Mexico, import basic foods that they themselves have historically produced, and in this case, such a culturally significant one.

These policy changes were extremely difficult on rural Mexicans who faced enormous challenges in maintaining rural livelihoods without state subsidies and price supports, among other factors, including environmental ones such as soil erosion and drought, and who also faced a loss of employment in agriculture—half a million agricultural workers were displaced between 1995 and 2005.[37] Farming remains important to rural Mexican households, as in many parts of the world, but often in conjunction with other income-generating activities, such as labor migration within Mexico and across national borders into the United States, and to a lesser extent Canada.

Neoliberal agricultural and trade policies have facilitated the growth in the cultivation of genetically engineered crops, and this has involved market concentration in the food system, notably among seed corporations. Three corporations, Bayer (which bought Monsanto), Corteva Agriscience (which merged Dow and DuPont), and Syngenta (owned by ChemChina), control more than 60 percent of the world's commercial seed market, and the top ten corporations control over three-quarters.[38] Yet despite this market concentration, many of the world's small-scale farmers do not rely on the corporate seed industry but rather save, use, and improve local or "traditional" varieties of seed. They do so for a variety of reasons: for example, farmers may not be able to afford industry seed and the associated input costs; they may prefer the taste and texture of local varieties; they may not reside near a reliable seed distributer and trust the quality of local seed over industry seed; or they may not want to relinquish control over their on-farm seed saving practices with intellectual property rights (IPRs) that accompany genetically engineered seed.

Genetically modified organisms (GMOs) or transgenic plants are the products of recombinant DNA techniques that use organisms, their parts, or their processes to modify or create living organisms with particular traits. This includes plants whose genomes contain inserted DNA material from other plants or species. Conventional plant breeding and farming practices also produce new gene characteristics in plants, but what makes plant breeding and farming different from genetic engineering is that they work at the level of the whole plant. In contrast, genetic engineering has the capacity to overcome the sexual incompatibility of different species and to identify, isolate, and relocate any gene from one organism to a recipient plant's genome. Genetically engineered crops include different types of varieties: herbicide-tolerant (Ht) varieties, pest-resistant (Bt) varieties, stacked varieties (which are both herbicide-tolerant and pest-resistant), and those with other characteristics such as added nutritional content (e.g., "golden rice" with vitamin A). A recent advance in genetic engineering is gene editing with CRISPR (clustered regularly interspaced short palindromic repeats) technology. Unlike other genetic engineering techniques, CRISPR does not insert foreign genes into plants but uses the protein Cas9 enzyme to edit DNA sequences and modify gene function
p. 263 in a more targeted and less expensive manner. Because CRISPR-Cas9 ↳ does not insert foreign genes into plants, but rather edits DNA sequences, the US Department of Agriculture has decided that the use of this

technology for plants does not need to be regulated. It is unclear, currently, whether CRISPR gene-edited plants will face regulation in other countries.

With the advance of biotechnology, plant biodiversity is valued as a source of genes for the development of new technologies, crop varieties, and pharmaceutical products. Agricultural biotechnology extends the commodification of seed because much of genetically engineered seed is accompanied by intellectual property rights, requiring users to pay a licensing fee in addition to the initial seed purchase. This fee runs counter to the widespread practice of peasants and farmers to select, save, and even exchange seed for replanting. Most attempts to enforce intellectual property restrictions on seed have thus far taken place in the Global North. A notable and well-publicized case of patent enforcement grew out of Monsanto's claim that a Canadian farmer, Percy Schmeiser, was growing Roundup Ready canola without a license. By charging a fee to use seed saved by farmers, intellectual property provides another way to overcome the free reproduction of seed, or seed's "biological barrier to commodification." The commercialization of seed, including IPRs, is one way that public resources or "the commons" are undergoing privatization or enclosure; it contributes to what David Harvey calls "accumulation by dispossession," or the accumulation of capital by undermining a group's access and control over the resources that it needs to maintain its livelihood.[39] Legislative and regulatory changes to protect intellectual property also erode farmer control over inputs and the farming process.

In first two decades of the twenty-first century, the United States was the country with the most biotech crops grown, followed by Brazil, Argentina, Canada, and India. In the Global South, Latin America is the region with the largest area devoted to biotech crops.[40] The cultivation of biotech crops has transformed agricultural practices and agrarian relations in those countries where it has been widely adopted. However, associated regulations and trade of GMOs have also influenced regions where they are not commercially grown on a large scale.[41]

In Mesoamerican countries—the center of biodiversity, and where maize originated—transgenic corn has been the focus of anti-GMO activism. In Mexico, an anti-GMO network and movement formed around the controversial finding of transgenic corn growing in traditional cornfields, despite the fact that the testing and commercial cultivation of GM corn was prohibited at the time. The commercial cultivation of transgenic corn in Mexico remains prohibited today except in authorized test plots.

Evidence of genetically engineered corn growing among traditional cornfields was found in the highlands of Oaxaca in 2001. Although there was a de facto moratorium on the scientific field-testing of genetically engineered corn at the time, and growing it was prohibited, the country imported transgenic corn from the United States for use as animal feed, grain for tortillas, and industrial processing. Small-scale Mexican cultivators likely encountered these imports in regional markets. At the time, most of this corn was a Bt variety that expresses the bacterial toxin *Bacillus thuringiensis*, which is poisonous to the European and Southwestern corn borers. These pests burrow into p. 264 ↳ the stem of the corn plant, causing them to fall over. In the United States, once transgenic corn has been harvested there is no mandatory labeling or segregation of it from conventional corn.

In response to the controversy, pro-maize and anti-biotech campaigns and networks, such as In Defense of Maize and Sin Maíz No Hay País (Without Corn, There Is No Country), emerged and expanded, drawing together environmental, food activist, independent peasant, and Indigenous rights organizations. Numerous academics, researchers, and scientists are also involved in these networks. Scientists who participated in the early years of the In Defense of Maize network were not against agricultural biotechnology per se, but rather against the testing and cultivation of transgenic corn, which was, at the time a Bt variety, designed to attack pests not found in Mexico. Concerned scientists and activists have also emphasized that Mexico is a center of biological diversity of maize, and that traditional maize has enormous cultural significance. Biotech crops like cotton have been grown in Mexico without the same degree of public attention or concern that has been given to maize. Since 2012, however, GM soybean has generated concern for Mayan honey producers in the Yucatán because GM pollen was found in honey samples destined for export.

Maize is the main crop grown throughout the country, the cornerstone of rural livelihoods, a key ingredient of culinary traditions and the national diet, and a powerful and longtime symbol of the Mexican nation. At times, maize invokes elements of shared culture across different scales of place, ranging from the small rural community or region to the nation state, but also beyond the borders of Mexico to Indigenous and rural Latin America. Anti-GMO activists focus on the risks of transgenic corn in particular, in other regions of Latin America such as Guatemala and Colombia.[42]

Supporters and advocates of biotechnology argue that GMOs provide an important tool for increasing food production and the nutritional content of crops, particularly as our climate changes and the world population increases. Debates over GMOs can be very polarized, but supporters and critics may have more complicated and nuanced positions on the topic—for instance, in opposition to (or support of) a *particular* type of genetically engineered crop, as is the case in Mexico with transgenic corn.[43] Additionally, much like with the Green Revolution, the benefits and problems of GMOs are unevenly experienced and distributed.

The neoliberal food regime has not only involved the growth of transnational agribusiness and food conglomerates, but also transnational networks of resistance and social movements as well. In Western Europe, early campaigns against GMOs were quite effective in mobilizing consumers around issues of food safety, ideas about preserving rural society, and ethical concerns about genetic engineering as defiling the natural boundaries between species. In the Global South, resistance to this technology focuses on the effects of GMOs on the environment and small-scale farmers' livelihoods, as well as the interconnected issues of property rights and biopiracy—or the appropriation of traditional knowledge and biological resources.[44] These issues have increasingly been adopted among activist networks spanning the Global South and North.

Conclusion

> "It would be accurate to say that corn is a central character in the history of capitalism, but it would be unjust to suggest that the migration and spread of corn is its only conceivable circumstance; resistance to the encroachment of corn is another. Corn is also so much more than that. It is a unique resource for the construction of a new reality, for change and social transformation."
>
> —Warman, *Corn and Capitalism*, 233–34

The once humble Mesoamerican staple has become a ubiquitous ingredient found in every aisle at the supermarket and a "flex crop" of global importance. Maize has always been a versatile crop with multiple uses, a key factor in why it was adopted and celebrated by small-scale farmers in vastly different ecological and climatic regions. Along with humans, our "plant kin" has shaped the direction of agricultural change. The plant's physical and physiological characteristics, and its adaptability and transportability, have also meant that maize was an ideal crop for commodification, industrial processing, and multipurpose agriculture. The overproduction of corn in the United States during the latter part of the twentieth century has had ripple effects across the US food chain and beyond, affecting the livelihoods of maize farmers and consumers in Mexico and elsewhere. In this way, the triumph of industrial corn presents challenges to smaller-scale farmers and subsistence producers. While agrarian political economy and the food regime approaches focus on policies, practices, and social relations of food, trade, and agriculture, these approaches can also draw our attention to the agency of farmers and consumers, as well as of the maize plant itself, in shaping agricultural practices.

The story of maize—from a traditional companion crop to hybrids and genetically engineered varieties—tells us a great deal about the transformation of agriculture under different periods of capitalism from mercantile and colonial, industrial to neoliberal. Maize is also an important part of the story when social movements and activist networks challenge GMOs, neoliberalism, and the global food system.

Notes

1. David Goodman, Bernardo Sorj, and John Wilkinson, *From Farming to Biotechnology: A Theory of Agro-Industrial Development* (Oxford: Basil Blackwell, 1987), 2.

2. Joseph Baines, "Fuel, Feed and the Corporate Restructuring of the Food Regime," *Journal of Peasant Studies* 42, no. 2 (2015): 299.

3. Rebecca Earle, " 'If You Eat Their Food …': Diets and Bodies in Early Colonial Spanish America," *American Historical Review* 115, no. 3 (2010): 688–713 See 698 on archeological studies of Spanish settlements in Florida that had squash and maize, 688 on diets, and 704 on admired foods, such as pineapple and cacao. In the sixteenth century, Juan de Cárdenas, a

doctor from Seville, wrote about corn's virtues (Arturo Warman, *Corn and* ↳ *Capitalism: How a Botanical Bastard Grew to Global Dominance*, trans. Nancy L. Westrate [Chapel Hill: University of North Carolina Press, 2003], ch. 2). See also Robert Launay, "Maize Avoidance? Colonial French Attitudes toward Native American Foods in the Pays des Illinois (17th–18th Century)," *Food and Foodways* 26, no. 2 (2018): 92–104.

4. USDA, FAS Grain, "World Agricultural Production" Circular Series WAP 11–23 Nov (2023), p. 25 https://apps.fas.usda.gov/psdonline/circulars/production.pdf.

5. Betty Fussell, "Translating Maize into Corn: The Transformation of America's Native Grain," in "Food: Nature and Culture," special issue, *Social Research: An International Quarterly of the Social Sciences* 66, no. 1 (1999): 42.

6. Ibid., 51.

7. Warman, *Corn and Capitalism*, 61.

8. CropLife Staff, "Chinese Growing More Corn than Rice," *CropLife*, 11-23 Nov (2023), p. 25 https://apps.fas.usda.gov/psdonline/circulars/production.pdf .

9. James McCann, *Maize and Grace: Africa's Encounter with a New World Crop, 1500–2000* (Cambridge, MA: Harvard University Press, 2005), 28–29.

10. Ibid., 106–10.

11. Harriet Friedmann and Philip McMichael, "Agriculture and the State System: The Rise and Fall of National Agricultures, 1870 to the Present," *Sociologia Ruralis* 29, no. 2 (1987): 93–117. These authors introduced and revised the food regime approach, which has also been taken up by other food scholars.

12. McCann, *Maize and Grace*, 1.

13. Ibid., 208.

14. Warman, *Corn and Capitalism*, 234–35.

15. Goodman, Sorj, and Wilkinson, *From Farming to Biotechnology*, 12.

16. Jack Kloppenburg Jr., *First the Seed: The Political Economy of Plant Biotechnology* (Cambridge: Cambridge University Press, 1988): 91.

17. Deborah Fitzgerald, "Farmers Deskilled: Hybrid Corn and Farmers' Work," *Technology and Culture* 34, no. 2(April 1993): 342.

18. McCann, *Maize and Grace*, 11.

19. Kloppenburg, *First the Seed*, 91.

20. Michael Pollan, *The Omnivore's Dilemma: A Natural History of Four Meals* (New York: Penguin, 2006): 45.

21. Ibid.

22. Cynthia Hewitt de Alcántara, "Economic Restructuring and Rural Subsistence in Mexico: Corn and the Crisis of the 1980s," Ejido Reform Research Project (San Diego: Center for U.S.-Mexico Studies / UNRISD, 1994): 26.

23. David Barkin and Billie DeWalt, eds. *Food Crops vs. Feed Crops: Global Substitution of Grains in Production* (Boulder, CO: Lynne Rienner 1990): 35; Joseph Cotter, "Before the Green Revolution: Agricultural Science Policy in Mexico, 1920–1950" (PhD diss., University of California, Santa Barbara, 1994): 258.

24. Jeffrey Pilcher, *"Que vivan los tamales!": Food and the Making of Mexican Identity* (Albuquerque: University of New Mexico Press, 1998): 116.

25. Barkin and DeWalt, *Food Crops vs. Feed Crops*.

26. Pollan, *The Omnivore's Dilemma*, 52.

27. Ibid., 53–55.

28. Baines, "Fuel, Feed and the Corporate Restructuring of the Food Regime," 303. See also Sean Gillon, "Flexible for Whom? Flex Crops, Crises, Fixes and the Politics of Exchanging Use Values in US Corn Production," *Journal of Peasant Studies* 43, no. 1 (2016): 117–39.

p. 267 29. Pollan, *The Omnivore's Dilemma,* 52.

30. Baines, "Fuel, Feed and the Corporate Restructuring of the Food Regime."

31. Ibid.

32. Mairon G. Bastos Lima, "Toward Multipurpose Agriculture: Food, Fuels, Flex Crops, and Prospects for a Bioeconomy," *Global Environmental Politics* 18, no. 2 (May 2018): 144.

33. Saturnino Borras Jr., Jennifer C. Franco, S. Ryan Isakson, Les Levidow, and Pietje Vervest, "The Rise of Flex Crops and Commodities: Implications for Research," *Journal of Peasant Studies* 43, no. 1 (2016): 93–115.

34. Bastos Lima, "Toward Multipurpose Agriculture."

35. Borras et al., "The Rise of Flex Crops and Commodities."

36. Although most yellow dent corn is for animal feed, the price of different types of corn are linked. See Timothy Wise, *Eating Tomorrow. Agribusiness, Family Farmers and the Future of Food* (New York: The New Press, 2019): 152.

37. Mamerto Pérez, Sergio Schlesinger, and Timothy Wise, *The Promise and Perils of Agricultural Trade Liberalization. Lessons from Latin America* (Washington, DC: Washington Office on Latin America, 2008).

38. Pat Mooney, *Blocking the Chain: Industrial Food Chain Concentration, Big Data Platforms, and Food Sovereignty Solutions* (Val-David, Québec: ETC Group, 2018), 8, accessed February 21, 2019, http://www.etcgroup.org/sites/www.etcgroup.org/files/files/blockingthechain_english_web.pdf; ETC Group. *Putting the Cartel before the Horse … and Farm, Seeds, Soil, Peasants, etc. Who Will Control Agricultural Inputs*, Communiqué No. 111 (Val-David, Québec: ETC Group, 2013), 4, www.etcgroup.org/putting_the_cartel_before_the_horse_2013.

39. David Harvey, *The New Imperialism* (Oxford: Oxford University Press, 2003), 147–48.

40. ISAAA (2018), http://www.isaaa.org/resources/publications/annualreport/2018/default.asp.

41. Elizabeth Fitting, "GM Crops and the Remaking of Latin America's Food Landscape," in *Food and Place: A Critical Exploration*, ed. Fernando Bosco and Pascale Joassart (London: Rowman & Littlefield, 2018): 52–65.

42. Fitting, *The Struggle for Maize*, 2011. See also Elizabeth Fitting, "Cultures of Corn and Anti-GM activism in Mexico and

Colombia," in *Food Activism: Agency, Democracy and Economy*, ed. Carole Counihan and Valeria Siniscalchi (London: Bloomsbury, 2014): 175–92.

43. This is discussed in greater depth in Fitting, *The Struggle for Maize*, chs. 1 and 2.

44. Rachel Schurman, "Introduction: Biotechnology and the New Millennium," in *Engineering Trouble: Biotechnology and its Discontents*, ed. Rachel Schurman and Dennis Doyle Takahashi Kelso (Berkeley: University of California Press, 2003): 9–11.

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