CORN

its role in the United States' Food Industry and Environmental Degradation

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Introduction

The Three Sisters were the essential Native American produce: beans, corn and squash. They were planted together in small symbiotic units, symbolic of the way this people lived in harmony with the natural world. Beans supplied nitrogen to the soil, corn supported the beans' growth, squash discouraged weeds and animal pests. Ironically, today corn is a symbol of the United States' incredibly negative impact on the climate, animals and people on Earth.

Americans do not consider themselves to be "corn eaters." People enjoy corn on the cob in the summer, corn chips and dip at parties, and occasionally find cornbread or canned corn at meals. However, every year, each American consumes less than a bushel of sweet/white corn, and over 35 bushels of field corn [1]. Corn plays an incredible role in many aspects of our daily lives, including the food and fuel industries. This is incredible.

Corn's rise to power in the United States is due to science, technology, nature, government policy, corporations. It has a great influence on the environment, and is a link between the food, oil and pharmaceutical industries. Its story is both amazing and alarming.

Zea mays

Zea mays, subspecies mays, is known to us as maize or corn. It evolved from the grass teosinte, which looks like a typical grass, lacking the ear that makes maize special [2, 3]. Teosinte originated in Central America, and can still be found growing wild in some regions [2]. In what has been called a "catastrophic sexual transmutation," it underwent a serious of mutations in a relatively short period of time that moved the plant's seeds from the top to mid-way up the plant (the male part remains at the top) [3]. This allowed the what would become the zea mays plant to produce 150-300 giant seeds, but also imprisoned them in the husk.

This strange new grass could not have easily survived had it not been for humans [1, 2]. Early Central American people quickly learned how to eat, store, plant and breed corn. European settlers were taught to plant corn by Native Americans. This crop flourished easily while their familiar wheat had difficulty adapting to the new climate. Its high yield, easy storage and multiple functions (food, feed and fuel) made it invaluable to our developing nation [4].

Agriculture

During the last century, America's food system has shifted from small farms to gigantic industrial farming system. Less than half of a percent of Americans today are farmers – generations ago a quarter of the population lived on a farm [1]. About 253,820 km^2 of land in the United States is used to grow corn (for comparison, New York State is about 141,000 km^2). We produce over 40% of the world's corn, and we use over 80% of it ourselves [1, 2, 4].

The scientific community's understanding of agriculture played a critical role in the industrialization of food. In the 1840s Justus von Liebig reduced a soil's health and growing potential to three letters: NPK [5]. The nitrogen, phosphorous and potassium levels in soil (and carbon dioxide levels in the air) had an amazing impact on plants' health in his experiments. Thus, the system of humus, minerals, and organisms living in the soil was forgotten, reduced to NPK. This reductionist science proved to have an impact on the environment.

In nature, nitrogen is freed from the atmosphere and put into the soil as ammonia by legumes and some other plants. Thus farmers had to rotate their crops periodically to allow soybeans to replace the nitrogen in the soil that corn (and other crops) had removed from it. German scientist Fritz Haber discovered in the first decade of the twentieth century how to convert atmospheric nitrogen into ammonia [6]. The Haber process permitted the creation of synthetic fertilizer, thus freeing agriculture from imported sodium nitrate, crop rotation and animal manure.

A few generations ago, corn was sold in burlap sacks with the farmer's name printed on it [1]. Farmers worked hard to make good corn with large kernels in neat rows on each insect-free ear. In 1856 the Chicago Board of Trade established a grading system for grain and corn [7]. This allowed agriculture to take advantage of the new technologies of the time – trains and grain elevators. It gave all farmers an equal opportunity to sell their crops into the growing "river of corn" that flowed across the country [1, 7]. The farmers' emphasis immediately switched from quality to quantity. It no longer mattered if an ear of corn's kernels were bright yellow or pale, as all #2 field corn was created equal in the eyes of the industry. Yield became the only thing important to farmers.

By the mid-twentith century, farmers' goal was to push zea mays to improve its yield. This mean improving the number of kernels per ear, ears per plant and/or plants per acre. Plants are bred so that they can live in incredibly close proximity to their neighbors. In the past century the density of planted corn has more than quadrupled: a typical farm can support over 30,000 genetically identical plants per acre [1]. Also available are genetically-modified corn plants that increase yield as well as resistance to insects, drought, etc.

The Haber process also freed agriculture from solar energy. Food production had been limited

by biology – how much nitrogen a plant could fix and manure livestock could create. Food was now enchained by petroleum, as the Haber process requires intense heat and pressure (electricity), and hydrogen gas obtained from fossil fuels [8]. Haber and scientists of his time were praised (in part by the 1918 Nobel Prize in Chemistry) for creating this seemingly endless supply of fertilizer, and thus food.

In the United States NPK became especially important after World War II when we were left with a huge warfare chemical surplus [1, 8]. Plants happen to do well in soil enriched with ammonium nitrate, a chemical in explosives. Thus the Department of Agriculture helped established the chemical fertilizer industry [1, 8]. (With this came the modification of war gases for use as pesticides.)

In addition to it being energetically costly to make, artificial fertilizer is a threat to the environment and public health. Ammonium nitrate in fertilizer is transformed into nitrous oxide, a potent greenhouse gas. Runoff from farms also contaminates drinking water and can have serious health consequences [9]. Many cities in corn-country issue "blue baby alerts" when nitrate levels in drinking water are especially high. If parents give children tap water, the contaminants can interfere with hemoglobin's oxygen-carrying ability [1, 9]. When these nitrates reach the Gulf of Mexico, they stimulate the growth of algae. The algae depletes the oxygen in the water, preventing all other animals from living there. The growing region of euthropication in the Gulf is currently as large as the state of New Jersey [1].

Any large-scale industrial farming or agriculture operation decreases the biodiversity of an area and modifies its ecosystem. Very few species are raised as meat or dairy animals, but these account for 20% of all land animal biomass [10]. The biodiversity of an ecosystem, from the microscopic to macroscopic organisms, is incredibly important in ways that science is only beginning to fully understand. In many countries other than the United States, policies have been established to help preserve biodiversity in agricultural and livestock [11].

During the last century, the government established certain practices to encourage high production and low prices. If the price of corn drops below a certain threshold (around $2.00 per bushel), the government compensates the farmers for the difference [1, 4]. A typical farmer could receive almost half of his income from this and similar government payments [1, 4, 8]. Paradoxically, farmers see the only way to get ahead is to grow more corn [1]. No matter what the price per bushel, a farmer will sell his corn.

Thus the American "corn surplus" developed, and with it a number of industrial systems and "food chains" for utilizing this new source of biomass [1, 4, 8]. Today, over 11 billion bushels of field corn is produced per year, up from a mere 4 billion bushels in 1970 [1]. Corn now plays an integral role in nearly every aspect of American life – from automobiles to plastics to dessert.

A wet milling plant isolates each part of the kernel so it can be used for specific purposes. The skin becomes vitamin & nutritional supplements, the germ is crushed for oil, the endosperm's complex carbohydrates are turned into hundreds of organic compounds [1]. Many of the mysterious ingredients on processed foods come from the endosperm, including citric & lactic acid, glucose, fructose, maltodextrin, ethanol, sobitol, mannitol, xanthan gum, modified & unmodified cornstarches, dextrins, cyclodextrins, MSG [1]. In addition, a great many of the compounds extracted from corn are not used in food. Wet milling uses five gallons of fresh water for every bushel of corn processed, and ten calories of fossil fuel for every one calorie of food [8]. This is obviously a huge investment in energy and natural resources.

For a typical farmer deep in corn-country, Coleridge's famous line from *Rime of the Ancient Mariner* applies: there is corn everywhere but not a kernel to eat. In the early 1900s, a typical family farm supplied nearly all the food for his own family and a dozen other people [1]. Today, a family corn farm of about 475 acres can feed 130 people [1]. Of course, the farmer can not eat field corn, so he must buy all his food elsewhere. Many farmers are in debt from buying the latest yield-increasing products, work additional jobs on the off-season, and depend heavily on their spouse's income and government payments [1, 12].

Copyrighted corn breeds and intricate breeding practices force farmers to submit to industry. The corn seeds a farmer buys at the beginning of each season come from a long line of inbred plants. These seeds exhibit heterosis, where their yield is much higher than any of their ancestors. However, the offspring of these seeds have a drastically smaller yield, so farmers must continue to buy seeds annually [1, 2]. This helped the corn industry grow and gain power.

Livestock

As prosperity has increased in this and other countries, meat has found its way into nearly every meal. The amount of meat and milk consumed globally is expected to double in the next half-century [10]. The rearing, feeding and slaughtering of livestock requires an astounding 30% of the planet's entire land surface and a considerable fraction of America's oil consumption [10, 8].

A concentrated animal feeding operation (CAFO) is the livestock industry's name for the system by which an animal is raised to slaughter. It does not resemble a farm, where animals graze in pasture within a nearly closed system supported by solar energy. In CAFOs, animals are crowded together with nothing more to do than eat, defecate and sleep. CAFOs are enabled by the huge supply of cheap corn, which gets animals to slaughter weight faster. The livestock's diet is supplemented with protein and fat by-products from other slaughtered

animals, nutritional supplements, antibiotics and other drugs [8]. A century ago, cattle were four or five years old when they were slaughtered; today they are 14-16 months [1]. Many cattle have been bred such that they have energy requirements that simply can not be met by grass [4]. (Even farm-raised salmon are being engineered to eat cheap corn [1].) The feed requires about a third of the arable land available worldwide [10].

A steer arrives at a CAFO from an off-site breeding farm weighing about 80 lbs. Every day, he eats about 35 lbs of feed (most of which is corn) and makes about 2 lbs of edible meat [1]. When slaughtered, a steer weighs about 1,200 lbs and provides 600 lbs of edible meat. Over his lifetime, he has 'consumed' the equivalent of 35 gallons of oil [1].

Ruminants such as cows efficiently digest grasses thanks to the system of microbes in their four stomaches. Forcing cattle to eat food in a CAFO that their bodies did not evolve to digest causes a number of health problems. The first of ruminants' stomachs are naturally pH-neutral, but corn causes acidosis. This can cause self-induced fasting, diarrhea, ulcers, bloating (to the point of suffocation) and liver disease. At slaughter, 20-70% of cattle are found to have liver abbesses [1]. Overfeeding encourages excessive growth of naturally-occuring intestinal organisms, which causes the potentially fatal conditions coccidiosis and enterotoxemia. Living in such close quarters and in precarious states of health makes animals susceptible to pneumonia and "feedlot polio." Many of these diseases are rooted in the food that the cattle eat, so a change in the food would change the prevalence of these diseases.

Many of the cattle's conditions can be "treated" using antibiotics. In the United States, more antibiotics are sold for use in livestock than in humans [1]. This leads to concerns about the development of 'superbugs,' which develop through evolution immunity to the administered antibiotics. Human health is also at risk, as we are eating these heavily-medicated animals. While controversial, many scientists believe that the use of antibiotics in livestock is not worth the potential risk to human health [13].

Americans have come to enjoy beef containing more intramuscular fat that is the result of the CAFO lifestyle. This 'marbling' of the flesh contains more saturated fat and less omega-3 fatty acids than the meat of cattle raised on grass. The USDA's grading system supports and rewards marbling [1]. This directly degrades the health of the American people.

In addition to issues involving public health, the energy crisis and animal rights, the livestock industry is a significant source of pollution. It contributes as least as much greenhouse gas as automobiles in the United States [10]. While the livestock industry's carbon dioxide production is only about 10% of civilization's total impact, other more harmful gases are produced [10]. The global warming potential (GWP) of other gases is measured relative to that of carbon dioxide. About 65% of nitrous oxide and 37% of methane comes from agriculture; these have a GWP 296 and 23 times that of carbon dioxide, respectively [10].

Also, 64% of ammonia pollution is from livestock; this contributes to acid rain. Incredibly, CAFOs are exempt from many anti-pollution laws [12].

Corn-derived food products

About 30% of a typical supermarket's 45,000 items contain corn [1]. These include processed food (bread, soda, soup, crackers, yogurt, frozen dinners), but also non-food items (toothpaste, cosmetics, trash bags, cleansers, charcoal briquettes, matches, batteries). It is impressive that corn can be used in such diverse ways. However, processed food can have a great effect on health and economy in the United States.

In 1957 scientists discovered how to convert glucose to fructose using enzymes, and the process for creating corn-derived fructose was perfected by the late 1960s [14, 15]. This permitted the creation of high-fructose corn syrup (HFCS). It is 55% fructose and 45% glucose and tastes exactly like sugar (sucrose). HFCS instantly became a cheap source of 'sweet,' a taste preference that is hard-wired into the human brain because carbohydrates are an excellent source of energy. Within years, food manufacturers replaced most sugar with HFCS [1].

High-fructose corn syrup is portrayed as a controversial health topic in the media [16]. However, it has been shown that some people may have a fructose intolerance, leading to irritable bowel syndrome-like symptoms [17, 18]. Some studies reveal that large amounts of fructose is simply not good for animals [19]. Regardless of the exact health effects, the consumption of HFCS and total sugar has increased considerably over the during the last thirty years [20].

Processed food is cheap, even though it requires more energy to manufacture and nutrients are removed. This seemingly contradictory practice is enabled by cheap corn. The food industry's pricing scheme is incredibly irresponsible, as it does not account for the 'true' cost of 'cheap' food. A \$0.99 hamburger has an immeasurable financial impact on taxpayers (through health care and subsidies to farmers), the environment (cost of pollution, soil health, energy), welfare of workers (in corn farms and slaughterhouses) the military (to protect and procure oil and energy).

A visit to any grocery store reveals that one can purchase an order of magnitude more in calories of processed foods than whole foods per dollar. This means that poorer populations have less access to nutritious foods and are thus more prone to certain diseases, including adult diabetes and obesity.

The United State's "corn complex" also has an impact on global health. An estimated 800 million people are starving worldwide [21]. Every corn-derived calorie an American consumes required several more tens (or even hundreds) of calories to create. With every step up the food chain or in processing food, the amount of food energy available decreases by about a factor of ten [1]. This wasted energy (and water) could be used to save starving people in this country and abroad.

Alternatives to the industrial food system do exist. Most other nations still use cane or beet sugar to sweeten most of their foods and still feed their livestock little to no corn [1, 8]. In the United States, organic foods are becoming increasingly popular. However, the regulations that certify food as organic are vague. There is debate about the magnitude of the impact of organic farming on the health of the environment, animals and humans [22]. Self-sustained polyculture farms that derive their energy nearly entirely from the sun have great promise [1, 23]. However, by their very nature, these types of farms must remain small and serve only the local community.[1] It is very difficult to escape the industrial food system entirely.

Ethanol

The energy and global climate crises are inseparable. Scientists believe that immediate solutions and alternatives to humanity's destructive habits must be found. The United States government has set the goal to reduce oil consumption by 20% in the next decade, primarily by using alternative fuels. One proposed alternative to gasoline is an increase in the use of E85, a fuel that consists of 85% ethanol and 15% gasoline.

Ethanol can be created from the glucose in a plant (usually corn) through fermentation:

$$C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2CO_2 \qquad 2C_2H_6O + 6O_2 \rightarrow 4CO_2 + 6H_2O + \text{heat}$$

While this seems relatively straight-forward, advances in technology over the past decades have made this process more energy-efficient. Since the early 1990s, a maximum of 10% ethanol can be added to any gas pump in America.

American car companies strongly support flex fuel vehicles (FFVs), which can run on anything from pure gasoline to E85. Less investment in research and development is required to make E85-compatible cars than developing hybrids. The government also allows FFV manufacturers to increase their average mile per gallon rating. This is an unjustified modification because there are only 2,000 E85 pumps to serve the six million FFVs [24].

[1] Typically 1,500 miles separate a food's origin and point of sale.

Corn growers and ethanol plants are also supported by the government. Ethanol producers receive about a 20% tax credit for every gallon of ethanol produced; a tax on imported ethanol further helps [24]. There are about 120 ethanol distilleries currently operational in the United States and 90 are expected to open in the next few years to meet the growing demand for ethanol [24, 25]

Accounting for as many factors as possible, one report[2] calculates that the ratio of fossil energy input to energy out (at refueling stations) is 1.23 for gasoline and 0.74 for ethanol [26]. Other reports estimate there to be little difference in energy balance between gasoline and ethanol.

In addition to ethanol's efficiency relative to gasoline, the source of the ethanol must be considered. Corn yields about 370 gallons per acre of ethanol, while a great many other plants yield more [27, 28]. Switchgrass and miscanthus can produce 1,150 and 1,500 gallons per acre, respectively [27]. In addition, the dollar and energy cost of producing ethanol using these grasses is about 50–70% less than that of corn. Corn is the favored ethanol source because there is already so much of it grown, and because the corn companies are so powerful.[3]

Ethanol and biofuel research is incredibly diverse [29, 30, 31]. Many scientists believe that cellulose-derived ethanol is the key to highly efficient energy production [32, 33]. This process relies on microbes to produce sugars from all parts of the plant containing cellulose, which are then converted into ethanol.

Beyond doubts about ethanol's potential as a fuel, there are a number of ethical concerns. Many people believe that it is not right to use food as fuel when millions of people are starving. The amount of corn required to fill one car's tank once with ethanol fuel could instead be used to feed a person for as much as an entire year [34]. The demand for ethanol is expected to double in the next year [24]. This will drive prices higher on everything that contains corn – cereal, chicken, milk. The United States is also the world's largest exporter of corn, so poorer nations will also suffer [20, 34].

It is especially difficult for scientists to be objective in studying ethanol and other alternative fuel sources, as is incredibly complex socially, economically and scientifically. This is currently a very hot topic with many unanswered questions and intense debate.

[2]This calculation is presented by Argonne National Laboratory to the National Corn Growers' Association.

[3]Cargill is the largest privately-owned company in the world.

Conclusion

Corn itself is not evil. It provides a good source of complex carbohydrates, fiber, antioxidants and some iron and protein [35]. However, corn has succeeded in completely infiltrating and dominating the American land and people; this can be considered evil. As consumers, we all must strive to "eat our view" [36]. Whether you are concerned about human rights, the energy crisis, public health, oil and militancy, animal rights or the world economy, corn plays an important role.

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A Conversion factors

Oil
1 barrel = 42 gallons

Corn
1 bushel = 56 lbs (in ears)
1 ear = 14 oz
1 cup kernels = 1 ear
1 bushel = 64 cups
1 acre = 180 bushels
1 acre = 30,000 plants

B Data

United States Corn Use

2005-6 US Corn Use by Segment		
Segment	Amount (billion bushels)	Percentage of total
Livestock Feed	6.1	54.5
Exports	2.1	18.8
Ethanol fuel	1.6	14.3
Corn-derived products	1.36	12.1
HFCS	0.53	4.7
Corn Starch	0.275	2.5
Corn Sweeteners	0.225	2.0
Other	0.190	1.8
Beverage Alcohol	0.135	1.2
Total	11.2	

Source: USDA industry statistics.

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