9

FARMING, THE ENVIRONMENT, CLIMATE CHANGE, AND WATER

Does agriculture always damage the environment?

From the perspective of deep ecology, all forms of agriculture damage the natural environment. When our early ancestors went from hunting and gathering to planting crops and grazing animals, they cut forests and redirected waterways. Wild plants and animals were domesticated, then progressively modified through selective breeding. If protecting nature is the central goal, these actions must be considered damage. Using a more utilitarian and socially centered perspective, however, changes to nature caused by farming would be viewed as damage only if they brought long-term costs to human society that exceed the short-term food production gain. Even if we use this more forgiving definition, many kinds of farming today do damage the environment.

It is useful to classify the environmental damage done by farming according to where it takes place: on the farm versus off the farm. Farmers themselves will suffer most from damage on the farm, while it is mostly non-farmers who suffer if the damage is off the farm and downstream. In an important way, politics sets the balance between these two kinds of damage. Farmers in poor countries lack political power, so they will

often find themselves trapped into using practices that damage their own farm resource base, and hence their own livelihood. Farmers in rich countries have considerable organized political power, so they will find it easier both to protect their own resource base and to get away with actions that pollute air and water downstream from farms, to the disadvantage of non-farmers.

In the poorest developing countries, most of the environmental damage done by agriculture takes place on the farm itself. Prime examples include the exhaustion of soil nutrients due to shortened fallow times, waterlogging of soils due to mismanaged irrigation, or the "desertification" of rangeland caused by excessive animal grazing. By harming the agricultural resource base itself, this sort of damage lowers productivity and helps keep farmers poor. Research presented at an Africa Fertilizer Summit in 2006 revealed that the shortening of fallow times in Africa was removing nitrogen from the soil at an average annual rate of 22–26 kilograms per hectare, far too much to be offset by current rates of fertilizer application, which average only 9 kilograms per hectare. The result of this "soil mining" was a deficit in soil nutrients that causes annual crop losses estimated at between $1 billion and $3 billion. Nor is this the end of the problem. As cultivated soils become exhausted, farmers will extend cropping onto new lands, cutting more trees and destroying more wildlife habitat. According to the World Resources Institute, land clearing for the expansion of unsustainable low-yield farming has caused roughly 70 percent of all deforestation in Africa.

In wealthy industrial societies, by contrast, environmental damage from farming usually results from too much input use rather than too little, and those who suffer most are usually not farmers. For example, excessive nitrogen fertilizer use leads to nitrate runoff and eutrophication of streams and ponds. In Europe, excess nitrates in water are a downstream health hazard ("blue baby syndrome"). In the United States, excessive nitrogen fertilizer use on farms in the Mississippi River

watershed contributes to an environmental calamity both within that watershed and also in the Gulf of Mexico, where a 6,000-square-mile "dead zone" is no longer able to support aquatic life. In the Florida Everglades, nitrogen and phosphorous runoff from sugarcane production has produced cattail growth so thick as to replace the native sawgrass, ruining the habitat of wading birds like storks, and then sucking oxygen from the water when the cattails die and decompose, which kills the fish.

Exploitation of river water for crop irrigation can harm migratory fish species, such as salmon, which are unable to move upstream through the narrow passages and turbines of dams. Concentrated animal feeding operations (CAFOs), designed to cut livestock industry costs by fattening thousands of animals for slaughter all within one crowded facility, often pollute both the air and water with toxic effluents, creating health risks for non-farming human populations living nearby. The poultry industry in just a single county in Delaware produces 200 million birds a year, and mishandled chicken waste has been a major source of eutrophication in the Chesapeake Bay.

What kind of farming is environmentally sustainable?

Environmental activists and agricultural scientists answer this question in dramatically different ways. Environmentalists usually prefer small-scale diversified farming systems that rely on fewer inputs purchased off the farm, and on systems that imitate nature rather than trying to engineer or dominate nature. Agricultural scientists tend to assume that there will be less harm done to nature overall by moving toward specialized high-yield farming systems employing the latest technology, because increasing crop yields on lands already farmed will allow more of the remaining land to be saved for nature. While environmentalists invoke the damage done by modern farming, agricultural scientists invoke the greater damage that

would be done if the same volume of production had to come from low-yield farming systems.

The environmentalist side of this argument was most eloquently presented in 1962 in Rachel Carson's landmark book, *Silent Spring*, which exposed the damage done by chemical pesticides both to human health and to wild animal species (including songbirds, hence the title). Carson's book led to a legal ban on the agricultural use of DDT in the United States and also to the formation of a broad and powerful environmental movement, which in 1970 secured passage of the National Environmental Protection Act, creating America's Environmental Protection Agency (EPA). Carson's thinking also reinforced a continuing quest among environmentalists for an alternative to high-input, high-yield farming.

One early pioneer in this search for "alternative" models of farming was Wes Jackson, who founded a Land Institute in Kansas in 1976, to promote farming based on polycultures of perennial crops rather than monocultures of annual crops. This approach did not prove to be a commercial success, but it was Jackson, in 1980, who began employing the term "sustainable agriculture" to describe his objectives. Responding to political interest in alternative farming systems, the Department of Agriculture in 1985 finally initiated a program to promote what it called low-impact sustainable agriculture, or LISA. Conventional commercial farmers panned it as "low income sustainable agriculture," but the idea gained traction with non-farming urban populations and with a younger cohort of countercultural farmers who had links to a back-to-the-land movement from the 1960s.

High-input farming did cause environmental damage in America during the second half of the twentieth century, but the earlier style of low-input farming had also been damaging. It was an extension of low-yield wheat farming into the southern plains of Kansas, Oklahoma, and the Texas panhandle in the 1920s, before synthetic chemical fertilizers or pesticides were in wide use, that produced America's single greatest

environmental disaster until that time, a drought-induced loss of topsoil that ruined farmlands across an area as big as the state of Pennsylvania, turning it into a "dust bowl." Roughly 400,000 farmers fled the dust bowl, many of them moving to California to work as migrants picking tomatoes and peas, a flow of environmental refugees unmatched in scale until Hurricane Katrina subsequently flooded out the population of New Orleans in 2005.

Following Carson's book, while environmentalists were concluding that chemical use to increase crop yields was inherently dangerous, commercial farmers and agricultural scientists sought instead to develop new chemicals that were less harmful and ways to apply them with greater precision to reduce runoff. Environmental advocates were not impressed with this "technical fix" approach; they wanted a more complete move away from highly specialized, highly capitalized "industrial" farming. Their views were later supported by a 2008 International Assessment of Agricultural Science and Technology for Development (IAASTD), which warned that using still more modern science to "increase yields and productivity" might do even more environmental damage.

Growing numbers of popular writers have embraced this view. In an apocalyptic 2008 book titled *The End of Food*, journalist Paul Roberts argued that the world's large-scale, hyper-efficient industrialized food production systems were heading toward an inevitable collapse because of the damage they had been doing to soils, water systems, and other "natural infrastructure." Alternative food advocate Michael Pollan wrote in 2008 that "the era of cheap and abundant food appears to be drawing to a close." In 2013, *New York Times* food columnist Mark Bittman described America's "hyper-industrial" agricultural system as having poisoned land and water, wasted energy, and made a major contribution to climate change. "We must figure out a way to un-invent this food system," said Bittman. Despite such popular sentiments, a preponderance of agricultural scientists and economists do not reject today's

large-scale, specialized, and highly capitalized farming systems as unsustainable. In fact, they view these systems as the best means available to contain environmental damage from farming.

What is low-impact or "precision" farming?

Commercial farming today has moved well beyond the indiscriminate chemical use practices that Rachel Carson properly criticized in 1962. Many of the early insecticides then in use have now been banned and replaced by chemicals that are less persistent in the environment and effective when applied in lower volume. Commercial farmers are always looking for ways to cut back on unnecessary chemical and fuel use so as to reduce costs, and by the end of the twentieth century they had found a number of technical means to do so. These new methods came to be labeled "precision" farming.

Beginning in the 1970s and 1980s, during an interlude of extremely high energy prices, farmers in the United States first learned to save diesel fuel by planting seeds in unplowed fields—a "no-till" approach to farming that also reduced erosion, conserved soil moisture, and sequestered carbon. They also switched from flood irrigation to less wasteful center-pivot sprays, or to laser-leveled fields with zero runoff, and to even more precise drip irrigation systems. Then, in the 1990s, they began using Global Positioning Systems (GPS) to auto-steer tractors in perfectly straight lines with zero overlap (saving more diesel fuel), plus soil-mapping and onboard computer systems to match chemical applications of fertilizer or lime more precisely to location-specific needs. The GPS told them exactly where they were in a field to within one square meter, and with variable rate application machinery they could deliver precisely the amount of water or fertilizer required in that part of the field. Infrared sensors can be used to detect the greenness of a crop, telling a farmer exactly how much more (or less) fertilizer might be needed. To minimize nitrogen runoff,

fertilizer can also be inserted into the soil in much smaller total quantities at exactly the depth of the plant roots, and in perfect rows exactly where the seeds will be planted. Also in the 1990s, farmers in the United States began planting genetically engineered soybean, corn, and cotton seeds that made it possible to control weeds without mechanical tillage and to control insects without as many chemical sprays.

Farmers took up these more precise methods to save money on chemicals, water, and diesel fuel, but the side result was a clear benefit to the environment. American agricultural output has increased by 40 percent since the early 1980s, but chemical fertilizer use, insecticide use, and herbicide use have all declined in absolute terms. Energy use, land use, and water use have declined most conspicuously on a per bushel of production basis. Department of Agriculture surveys reveal that between 1980 and 2011, energy use per bushel of corn production fell 43 percent. Land use per bushel fell 30 percent. Soil erosion per bushel fell 67 percent. Irrigation water use per bushel fell 53 percent. And greenhouse gas emissions per bushel fell 36 percent.

The United States has not been alone in making this technical move in commercial farming toward reduced input use per bushel of production. In 2008 the Organisation for Economic Co-operation and Development (OECD) in Paris published an important review of the "environmental performance of agriculture" in the 30 most advanced industrial countries of the world (those with the most highly capitalized farming systems). The new data showed that between 1990 and 2004, total food production in these countries increased in volume by 5 percent from an already high level, yet adverse environmental impacts had diminished in nearly every category. The area of land taken up by agriculture declined 4 percent. Soil erosion from both wind and water was reduced. Water use on irrigated lands declined by 9 percent. Energy use on the farm increased at only one-sixth the rate of energy use in the rest of the economy. Gross greenhouse gas emissions from farming

fell by 3 percent. Herbicide and insecticide spraying declined by 5 percent. Excessive nitrogen fertilizer use declined by 17 percent. Biodiversity also improved, as increased numbers of crop varieties and livestock breeds came into use.

True believers in the promise of precision farming expect there will be no end to the impact-reducing gains that can be achieved. Their long-term vision includes small solar-powered robots working farm fields in groups, hoeing weeds and picking off bugs 24 hours a day without any polluting chemicals or fossil fuels at all, then harvesting the crop with almost no human supervision required. Even if this fantasy became possible, most environmental advocates would refuse to see it as progress. They generally do not endorse modern precision farming because it favors highly capitalized industrial-scale operations, something they reject on principle. The small, diversified farms they favor cannot make use of the costly and specialized machinery that is a key component to most modern precision farming. In addition, environmental advocates instinctively reject the notion that a biological system such as a farm can be sustainably and safely precision-engineered through science. They believe, with Rachel Carson, that nature will always find a way to strike back against human arrogance of this kind.

Do fragile lands, population growth, and poverty make farming unsustainable?

These are popular explanations for environmental damage from farming, but institutional arrangements are usually more important.

The concept of "fragile" land can be misleading. It is true that many poor countries farm on sloping lands or irregular lands with thin and badly weathered soils, all subject to the damaging extremes of heat, flood, and drought. In many tropical countries, soil nutrients leach away immediately when trees are cut, leaving a baked and barren landscape on which only

weeds will grow. Under proper management, however, these less productive tropical lands can be improved dramatically and farmed sustainably. When farmed with adequate fallow time, or limed to the correct acidity, or terraced and mulched to capture and keep more moisture on leveled soil, or planted to several different crops at the same time (intercropped) to reduce vulnerability to pests, the productive potential of such less-favored lands can be sustainably increased.

Some argue that poverty itself is a cause of environmental damage in farming, because poor farmers who live from hand to mouth cannot afford to wait for resource-protecting investments to pay off. Yet many poor farming communities do invest to protect their resources, if the political and institutional circumstances are right. They are more than willing to build and maintain terraces, plant trees, and protect rangelands from overgrazing when effective "common property resource" (CPR) systems are allowed to operate at the local or village level. These informal systems protect local forests, streams, ponds, and grazing lands by allocating equitable use to insiders while denying access to outsiders. Such systems are good at blocking the "tragedy of the commons," a pattern of environmental destruction that arises in systems of open access (Garrett Hardin, the influential ecologist who named this danger in 1968, should have called it the "tragedy of open access"). Within a well-managed commons systems, even poor communities can avoid environmental tragedies.

Commons systems are vulnerable to breakdown, however, if powerful outside institutions, such as colonial administrators, international companies, forestry department bureaucrats, megaproject engineers, government land-titling agencies, or centralized irrigation authorities, move in to take control away from local community leaders. Local farmers who sense that they are about to lose control of their resource base will at that point stop making investments in resource protection. They will begin using up the resource base as fast as they can—cutting the trees, plowing up terraces, over-grazing the range,

over-fishing the ponds—before the outsiders take it away. Poor farmers who have control as well as access can be conserving farmers; if control is taken away, they will use their access to exploit rather than conserve.

Well-functioning common property systems in poor countries can also break down if local leaders become corrupt, or due to excess population growth. If population density increases beyond a certain point, the value per person of protecting the resource will decline so much for insiders as to demotivate efforts at protection, just when more outsiders will be attempting to gain access. At this point, effective resource protection can require switching to an individual private property system, one that restores individual payoffs for resource-protecting actions while handing the problem of excluding outsiders over to the police. If this transition to individual land ownership is made successfully, a further increase in population density need not threaten the resource base at all. In fact, greater population density makes affordable greater labor investment in protecting the land (mulching, terracing, etc.) and increases the affordability of productivity-enhancing investments in rural roads, power, and irrigation. One example from Africa is the experience of Machakos District in Kenya, where farmers in this densely settled semi-arid area avoided serious damage to their marginal soil endowments even as population increased. This occurred thanks to clearly titled land ownership that motivated heavier labor investments in terracing systems, use of more fertilizer, and a shift to higher-value crops for sale in nearby urban markets.

Do cash crops and export crops cause environmental harm?

Shifting from food crop production to a more specialized cash crop production for export is frequently cited as a cause of both economic dependency and environmental harm. There are some cases that support this generalization, for example in Central America in the 1960s and 1970s, when landlords

introduced chemical-intensive cotton production and evicted traditional peasants growing maize and beans. Yet the cash crop versus food crop dichotomy is usually misleading, because a number of food crops in the developing world are at the same time cash crops (for example, rice in Asia), and many cash export crops (such as cocoa in West Africa) are grown by small farmers in the same fields with food crops, in an environmentally friendly intercropping system.

Cash crops for export are not inherently less rewarding for small farmers to grow, or more damaging to the environment. Exported cash crops are often tree crops or perennials that provide better land cover and more stable root structures than annual food crops. In Africa, some kinds of perennial export crops—such as tea or coffee, planted along the contour of sloping lands, or oil palm planted in low-lying areas—can protect the soil much better than food crops requiring annual tillage, such as maize. At least a partial switch to higher-value cash crops helps farm families with limited land and labor earn the income they need to pay for their children's school expenses. Farmers will typically switch part of their land to cash crop production, then use some of the income to purchase improved seeds and fertilizer, allowing a simultaneous boost in food crop production on the rest of their land.

Do farm subsidies promote environmental damage in agriculture?

Yes. Most subsidy policies work by giving farmers artificially high prices for their products, which induces them to use excessive fertilizers, pesticides, and irrigation water in an effort to boost crop yields as high as possible. In Korea, where rice farmers are heavily protected (with a guaranteed price roughly five times the world market price) pesticide use is extremely high, at 12.8 kilograms per hectare. In France, where farmers have less price protection, pesticide use is less than half as high, at 4.5 kilograms per hectare. In the United States, where there is even less protection, pesticide use is only 2.3 kilograms per

hectare. And in Senegal, where farmers get almost no protection at all, pesticide use averages only 0.1 kilograms per hectare. In most of Africa, farmers are often taxed rather than subsidized (a symptom of their political weakness), which frequently results in too little chemical use rather than too much. Fertilizer use in most of Africa is insufficient for replacing the soil nutrients taken up by crops.

When subsidies to farmers go up, input use often goes up in lock-step. Between 1970 and 1990 in Thailand, as income protections for farmers increased, fertilizer use per hectare increased nearly sevenfold. In Indonesia in the 1980s, where the government subsidized fertilizer purchases directly by as much as 68 percent, chemical use increased 77 percent over one five-year period. In India, when the government began to subsidize 86 percent of the electric bill for pumping irrigation water in the Punjab, groundwater tables began dropping at an unsustainable rate of about 0.8 meters a year.

In rich countries, farmers are not only powerful enough politically to demand the subsidies that encourage excessive input use, they are also powerful enough to avoid being held accountable for the resulting downstream environmental damage. Because of farm lobby strength, the air and water pollution that emanates from farms in rich countries is regulated far less than pollution from other industries. In the United States, the agricultural sector is significantly exempt from the regulatory structures of both the original Clean Air Act and Clean Water Act, because pollution from farms does not come from a "point source."

Despite the dead zone in the Gulf of Mexico, Congress does not regulate excess nitrogen runoff from farms and does not tax farm fertilizer use. Instead, it has created voluntary programs that pay farmers to take land (temporarily) out of production, or to cultivate their land in ways that reduce runoff. In 2010, these incentive-based, voluntary conservation programs operated by the U.S. Department of Agriculture (USDA) cost taxpayers $5.5 billion. Instead of using a "polluter pays"

principle, the government actually pays the polluter. Even in extreme cases such as chemical pollution in the Florida Everglades from heavily subsidized sugar farming, strong regulations are routinely blocked by industry. In 1996, when Vice President Al Gore proposed taxing sugar growers to finance an Everglades clean-up project, a direct phone call from a Florida sugar baron to President Bill Clinton resulted in the tax proposal being set aside.

A more recent example of the power of U.S. agriculture to resist environmental regulation can be seen in the case of climate change policy. In 2009, when the House of Representatives passed the Waxman-Markey bill to create a cap-and-trade system to limit greenhouse gas emissions, the entire agricultural sector was left "uncapped." Instead of being subject to caps under this bill, farmers would have been entitled to profit by selling "offsets" to industries in sectors that were capped. The offset would be based on a voluntary reduction in emissions, or an increased sequestering of carbon—things a farmer might be doing anyway.

One of the few environmental policy instruments strong enough to resist the farm lobby in the United States has been the 1973 Endangered Species Act. For example, in 2008, a lawsuit filed under that act by the Natural Resources Defense Council forced the Bush administration's Fish and Wildlife Service to divert more than 150 billion gallons of water away from irrigated farming in the San Joaquin Valley, in California, so as to protect the delta smelt, an endangered 3-inch bait fish. Environmentalists know that their best chance, in a battle against farmers, is usually to move the action out of Congress and into the courts.

How will climate change affect food production?

Climate change will affect food production in complex ways, and in different ways at different latitudes. In the tropics higher temperatures will damage farming, since some crops

are already being grown near the upper range of their biological heat tolerance, but in some higher temperate zone regions warmer weather will mean longer growing seasons, and perhaps the chance to add a second seasonal crop. Average rainfall and rainfall variability will change as well, in ways far more difficult to predict. A warming earth will be, on average, a wetter earth, due to accelerated ocean evaporation leading to increased cloud formation, and this can be good for farming. Other things being equal, increased carbon dioxide (CO_2) in the atmosphere will also help farming, since plants need to take in CO_2. This is known as the carbon fertilization effect. But increased atmospheric ozone, another greenhouse gas, can slow plant growth.

In North America, longer growing seasons at upper latitudes, more rainfall overall, and greater carbon fertilization may actually provide net benefits to farming. According to the Intergovernmental Panel on Climate Change (IPCC), crop yields in North America are expected to increase by 5–20 percent during the first several decades of the twenty-first century, due to climate change. At the same time, these gains will be uneven across the region, and weather variations are likely to be more extreme. Experts disagree on whether the 2012 summer drought in the United States was linked to long-term climate change or to short-term factors such as a cyclical La Niña effect.

The impacts of climate change on farming in the developing world are likely to be more damaging. One 2009 projection done by the International Food Policy Research Institute (IFPRI) was based on a linked computer model that incorporated both a food supply-and-demand component and a biological crop growth component, one that captured yield changes driven by temperature changes within 281 different spatial regions around the world. The temperature changes expected within these spatial regions, out to the year 2050, were calculated based on modeled scenarios generated from the IPCC's 2007 4th Assessment Report. The results of this

exercise were alarming. Rice production in the developing world in 2050 was expected to be 14 percent lower with climate change compared to without, and wheat production in the developing world was expected to be 34 percent lower due to climate change. In South Asia, specifically, wheat production was projected to be 49 percent lower in a 2050 world with climate change, compared to a world without climate change. When IFPRI then put these projected production impacts into its economic model, it estimated the higher food prices these climate effects would generate and concluded that there would be a 23 percent increase in the numbers of malnourished children expected in 2050 in a world with climate change, compared to a world without.

Two kinds of policy response are available to this threat. One would be "prevention," in the form of a redoubled effort to slow climate change, limiting any further temperature rise to no more than 2 degrees Centigrade, by somehow keeping atmospheric concentrations of CO_2 from exceeding 450 parts per million. This, however, would require a sharp downward adjustment in current fossil fuel consumption trends for countries such as China and India, as well as the United States and Europe. Such a response is politically unlikely, because it would imply much slower economic growth, at least until the costs of wind and solar power come down. A second option, favored by IFPRI, is to recognize the high probability of future climate change and to help developing countries adapt their farming systems by making larger investments in irrigation expansion and efficiency, rural roads, and agricultural research. If an added $7 billion were properly spent every year for such purposes, the adverse impacts of climate change on food production might be offset. This is a small amount of money relative to the budgets of today's major governments (the United States spends 100 times this amount on the Defense Department every year), yet political support for spending this money in the developing world is difficult to mobilize.

Does agriculture contribute to climate change?

Agriculture globally is a major contributor to climate change. The expansion of crop farming releases Co_2 into the atmosphere when trees are cut to clear land, and also when the soil is disturbed. Heat-trapping gases are also released when fuel is burned to manufacture fertilizer, or to power farm machinery, and when rice is grown in flooded paddy fields, which give off methane gas, more than 20 times as powerful in trapping heat as CO_2. Livestock production is an even more potent source of greenhouse gas emissions, because of the clearing of lands for pasture, and also because so much crop farming today goes for animal feed purposes. Moreover, the animals themselves are a source of greenhouse gas emissions, principally in the form of methane released from the digestive processes of ruminant animals (cattle, goats, sheep) that depend on microbial fermentation of fibrous grasses and feeds, and also from animal manure, which emits gases such as methane, nitrous oxide, ammonia, and carbon dioxide. The Intergovernmental Panel on Climate Change (IPCC) reported in 2007 that the agricultural sector overall was the source of 10–12 percent of total global anthropogenic emissions of greenhouse gases. If we add emissions from fertilizer production, food transport, refrigeration, consumer practices, and waste management, somewhere between one-fifth and one-third of all greenhouse gases emitted by people come from the food and farming sector, according to a 2012 analysis from the CGIAR Research Program on Climate Change, Agriculture, and Food Security. In the United States specifically, if only on-farm emissions are considered, agriculture accounts for somewhere between 7 and 8 percent of all greenhouse gas emissions.

Calculations of this sort are contentious and sometimes flawed. For example, in 2006, the United Nations Food and Agriculture Organization (FAO) released a report titled *Livestock's Long Shadow: Environmental Issues and Options*, which estimated that livestock production worldwide was responsible all by itself for 18 percent of all human-induced

greenhouse gas emissions, "a bigger share than that of transport." In generating this high percentage, the FAO followed a life cycle analysis approach that considered not just greenhouse gases from the animals themselves—including methane and nitrous oxide from the digestive systems and manure of the animals—but also emissions from a large number of associated activities such as land-use changes (converting forest to pasture), the burning of fossil fuels to produce animal feed, plus emissions from animal processing and transport. The surprising findings of the report prompted an animal welfare organization, PETA, to chide former vice president Al Gore for having failed to mention reduced meat consumption as one powerful way to prevent climate change.

It later came to light that this 2006 study was an exaggerated estimate, because it had compared a full life cycle analysis of the livestock industry to only a partial life cycle analysis of other sectors. For example, in the transport sector it counted greenhouse gas emissions from the gasoline burned by cars, but not the CO_2 emitted from factories that assembled the cars, or from the factories that manufactured the steel, glass, plastic, and rubber from which the cars were made. Authors of the FAO report conceded this flaw, but livestock industry critics continued to reference the study, and they even produced a dubious study of their own claiming that livestock were actually responsible for 51 percent of global greenhouse gas emissions.

One useful message from the original FAO study was that livestock systems based on extensive grazing are just as prone to produce greenhouse gas emissions as systems based on confined feeding. Cattle raised exclusively on grass take far longer to reach a market weight than cattle finished in a confined system, meaning more months or years of digestive methane and nitrous oxide emissions per pound of meat. As for confined systems (concentrated animal feeding operations, or CAFOs), they generate less methane and nitrous oxide per pound of meat, but usually much more CO_2, because of the diesel fuel burned in growing the feed grain.

Returning to a more traditional farm production system may seem a tempting way to reduce greenhouse gas emissions, but given today's much greater market demand for food, including animal products like meat, traditional systems would actually result in an increase in emissions. In 2010, a team of scientists at Stanford estimated that if world food consumption in 2005 had to be satisfied with the average crop yields of 1961, the total area of cropland under production worldwide would have to more than double, a damaging change in land use that would release sequestered carbon from forests and soils and increase global greenhouse gas emissions from agriculture roughly fivefold. This same study then asked how actual greenhouse gas emissions in 2005 would have changed if the world returned not only to 1961 crop yields, but also to 1961 per capita consumption levels. Moving back to a 1961 diet (one that depended far less on meat consumption) would reduce greenhouse gas emissions, but only enough to offset about half the damage done by moving back to the lower 1961 crop yields. The lesson from this study was that the worst possible situation for climate change would be a world that retains the current level of meat consumption but moves back to 1961 (pre-green revolution) crop yields.

Is the world running out of water to irrigate crops?

For farmers everywhere, water is destiny. Producing one kilogram of wheat requires the use of about 1,000 liters of water, and paddy rice requires twice this amount. The earth's freshwater supply is not diminishing overall, since it is renewed every time it rains, and about 60 percent of farm production in the developing world is still based on rainfall alone. Yet in regions where rainfall is uncertain or inadequate, irrigation techniques that bring freshwater from surface streams or from underground aquifers to the roots of crops are essential. Irrigated farming is the most reliable and often the most productive kind of farming; irrigated land makes up about

one-fifth of total arable area in the developing world, yet it provides two-fifths of all crops harvested and close to three-fifths of cereal production.

Total irrigated land area has doubled over the past 50 years, and globally today about 20 percent of all cultivated land is under irrigation. Roughly 70 percent of all the water we take from aquifers, streams, and lakes now goes into agriculture. Because the most promising sites for irrigation were developed long ago, the United Nations FAO expects irrigated area to grow more slowly in the years ahead, by only 6 percent between 2009 and 2050. This may not be enough to keep pace with future production requirements.

Expanding the use of irrigation water for agriculture will be difficult for several reasons. First will be an unavoidable increase in competition for freshwater from urban users, but second will be the needless degradation of some past irrigation sites. Poor drainage of irrigated lands has left some lands waterlogged or saline. Basins of dams have silted up, reducing capacity. In many large rivers, excessive withdrawals have left as little as 5 percent of the former water volume in-stream, and some rivers no longer reach the sea year-round. Nearly 40 percent of irrigated area now depends primarily on groundwater, yet aquifer depletion is a growing threat because rates of pumping have proved nearly impossible to regulate. According to one 2012 estimate published in *Nature*, roughly 1.7 billion people now live in areas where groundwater resources or groundwater-dependent ecosystems are under threat.

What can be done to improve water management in farming?

The first and most important step is to reduce water waste. The technical means available include shifting from flood irrigation to more precise spray-and-drip systems, leveling fields to eliminate runoff, and lining irrigation canals to reduce seepage. The policy steps needed include ending subsidies for

cheap electricity that encourage excessive pumping (in India, for example), establishing water users' associations to regulate access, and creating water markets based on tradeable water rights.

Private water markets have saved farming in some dry parts of Australia. One example is the Murray-Darling Basin, where the Australian government in the 1990s shifted from building dams and subsidizing water to a policy that separated water rights from land rights. This allowed farmers with less need for water to sell their rights to farmers who needed more. Total water availability was falling in this basin, yet the income of farmers remained high, thanks to the operation of this water market. As water availability went down, the price of water went up, which encouraged growers of thirsty low-value crops such as rice to sell some of their water rights to growers of higher-value crops such as vegetables or grapes. The system allows willing buyers and willing sellers to make deals, which in the end allocate scarce water to its highest value use. Water trading systems for farmers also operate at the state level in the western part of the United States, in Arizona, New Mexico, Colorado, and California.

While reducing water waste in currently irrigated regions, it will be equally important in the years ahead to extend irrigation coverage to regions where rainfall alone does not allow crop farmers to prosper. In Africa today, only 4 percent of cultivated land is irrigated, and 41 percent of annual farm production comes from lands that are both hot and dry. Farmers on these dry lands are pushed back into poverty every time the rains fail. The irregular topography of much of Africa, plus poor rural road and power infrastructures, have discouraged investments in irrigation. Building dams also encounters opposition from environmental groups. Because so many non-governmental organizations (NGOs) are now opposed to dams, the World Bank has virtually stopped financing such projects in the developing world. NGOs tend to favor small-scale irrigation alternatives such as rainwater harvesting,

bucket irrigation, treadle and pedal pumps, and small earthen dams, yet these options are hard to scale up and they carry excessive labor costs in much of rural Africa.

Citizens in today's rich countries, who gained prosperity in part by building dams to develop 70 percent or more of their own hydroelectric potential, might wish to think twice about telling Africa—where only 3 percent of potential has so far been developed—that dams are a bad idea.

10

LIVESTOCK, MEAT, AND FISH

How are farm animals different from crops?

In some respects, they are not so different. Human beings have eaten animals—including fish—from the beginning, and we have bred domesticated animals to serve our food purposes in much the way that we have bred crops. Moreover, market forces are pushing modern livestock production systems and modern crop production systems in roughly the same direction, toward increased specialization, automation, capital investment, and much larger scale. Consumer prices for animal products have consequently fallen over the long term, once again parallel to the long-term decline in crop prices.

In at least three respects, however, farm animals are significantly different from farm crops. First, and most obviously, they require more intensive management at a much higher ethical standard, because unlike plants they move about when not confined and maintain complex social and emotional lives. Second, farm animals must themselves be given food, often in large amounts, making the food products we derive from animals more expensive. Third, farm animals produce manure, which is a valuable product for restoring soil nutrients if managed properly; if mismanaged, however, it becomes a human health hazard and a damaging source of water and air pollution.

Is meat consumption increasing, or not?

Globally, meat consumption has been increasing at a rapid rate, tripling over the past 50 years. To sustain this higher consumption, herders and livestock producers around the world are now managing more than 26 billion animals at any one time, triple the 1970 number. The earth, in other words, is now supporting four times as many agricultural animals as people.

The driving factor behind this global increase in raising animals for food has been personal income growth. As societies become more wealthy, people almost invariably use a part of the higher income to purchase more meat, milk, and eggs. In wealthy regions such as Europe and North America, average annual per capita meat consumption has reached as high as 83 kilograms, far more than in less wealthy regions such as Latin America (58 kilograms), East Asia and the Pacific (28 kilograms), or Sub-Saharan Africa (11 kilograms). In rich countries, meat consumption per person is no longer increasing, but in the transitional countries of Asia and Latin America it still has considerable room to grow, and even more in the poor countries of Africa. According to one projection by the International Food Policy Research Institute, between 2010 and 2050 per capita meat consumption in Latin America is likely to rise by 33 percent, in East Asia and the Pacific by 86 percent, and in Sub-Saharan Africa by 118 percent (from a much lower level). Rich countries are the big meat consumers today, but in the decades ahead nearly all of the increase in meat consumption will take place in the developing world.

Most nutritionists endorse the consumption of some meat and dairy products (in addition to mother's milk, of course) as a source of beneficial micronutrients such as iron, zinc, calcium, and vitamins A and B12. Most of these same micronutrients are also available from plant sources, but in a form less easily taken up by the human body. Animal products can be particularly valuable for children going through a critical phase of accelerated physical growth and brain development in the first two years of life, and also for women with higher

iron requirements in their reproductive years. At the same time, excessive consumption of meat and animal products is associated with a number of poor health outcomes, including a variety of cancers, heart diseases, and stroke. In urban China between 1982 and 2002, when meat and dairy products in the average diet increased from 11 percent by weight up to 25 percent, the prevalence of diabetes, hypertension, heart disease, and stroke all increased sharply as well.

Meat consumption per capita has finally leveled off in today's rich countries, and in the United States it has actually begun to decline, falling by 10 percent between 2004 and 2012. The reasons for this decline include the post-2007 economic recession, higher meat prices linked to higher animal feed costs (linked in turn to an increased use of corn for ethanol), growing health concerns within an aging generation of baby boomers, plus increased public awareness of the many environmental and animal welfare concerns linked to modern livestock production.

This recent decline in meat consumption in the United States includes little in the way of a shift toward purely vegetarian diets. Small segments of the American public have always maintained vegetarian diets by abstaining completely from meat consumption, including poultry and seafood (but usually not eggs and dairy products). Currently a bit more than 3 percent of Americans identify themselves as vegetarians of this kind, which is up from roughly 1 percent four decades ago. A smaller share of these individuals even opt to consume no animal products at all, maintaining what is called a "vegan" diet. Particularly among health-conscious or countercultural younger people, vegetarian and vegan diets gain favor. Film stars ranging from Brad Pitt to Woody Harrelson have made it known that they are vegetarians, and in 2010 former president Bill Clinton followed his daughter's lead and adopted a vegan diet (after getting two stents on top of quadruple bypass surgery), explaining that he wanted to live to be a grandfather.

Most of the recent reduction in meat consumption in the United States reflects neither strict vegetarianism or veganism, but simply an increased frequency of meatless meals or meals with less meat, particularly red meat. This trend has been promoted since 2003 by public health professionals through a Meatless Monday campaign, which in 2012 claimed to have a national participation rate of 18 percent. The original goal of the campaign was to cut saturated fat consumption in the United States by 15 percent, down to a USDA-recommended level. The only large nation in which full vegetarianism is widespread is India, where an estimated 31 percent of the population (mostly Hindus and Jains) are vegetarians. In Europe, vegetarians are most prevalent in Italy (10 percent of the population) and least prevalent in France (only 2 percent).

Is a vegetarian diet healthier?

Dietary health requires a balance of nutrients, and for most people meat is a convenient part of this balance, but it is not strictly necessary. The Mayo Clinic confirms that even for growing children and adolescents vegetarian diets can be safe and healthy. Getting protein is not a problem, since vegetarians who are not vegans can get animal protein from milk and eggs, and even vegans can get abundant protein from beans, legumes, and nuts. Calcium is not a problem for vegetarians who consume dairy products, and vegans can get calcium from green vegetables or from products fortified with calcium, such as soymilks, cereals, and juices. Vegans must take special care to get vitamins D and B12; the latter in particular may require seeking out fortified foods or supplements.

It can be more convenient to secure the needed balance of nutrients from a less restrictive non-vegetarian diet, but non-vegetarians can of course lapse into imbalances of other kinds. Non-vegetarian diets too often include inadequate helpings of fruits and vegetables, too much red meat, too many processed meats like bacon, sausage, and salami (containing

risk-inducing nitrites as preservatives), and too many overcooked charred meats that carry cancer risks. When it comes to health, what matters most about meat is the quantity consumed and the way in which it is processed or cooked, not the fact that it is meat. One 2005 study from the German Cancer Research Center compared health-conscious meat eaters to vegetarians and found no difference in mortality rates.

In some societies, purely vegetarian diets are simply not an option. On drylands in Africa where there is not enough water for vegetable crops, communities could not be sustained without cattle, sheep, and goats, which are ruminant animals with an extra stomach, allowing them to thrive on grasses that people cannot digest, converting those grasses into meat and milk for people. Likewise in arctic regions, human societies could not survive if they did not eat meat from fish and animals. Even in agricultural societies where producing vegetable food is an option, the sale of meat or milk from animals is often an essential income source for poor people who lack access to cropland.

If people in rich countries ate less meat, would hunger be reduced in poor countries?

Yes, but only by a small amount. If meat consumption declined, international meat and animal feed prices would also decline, but this would matter little for the vast proportion of hungry people, because they do not consume much that comes from the world market, and particularly not meat or animal feed. What these poor people need is more income to purchase rice, white maize, sorghum, millet, yams, cassava, or banana in their own local markets, not a lower international price for meat and feed. Most of the effects of lower meat consumption in rich countries would be confined to those same rich countries. Fewer cattle would be grazed on rangelands in Texas or Australia, but since these lands are too dry for growing crops, they would simply go unused. Less corn and soy would be

produced for animal feed, and this would free up some more land for wheat and rice production, but the impact on international wheat and rice prices would be small.

The International Food Policy Research Institute has used a computer model of global agricultural markets to estimate the reduction in hunger that would result from a 50 percent reduction in per capita meat consumption in all high-income countries, from current levels. Under this extreme and unlikely assumption, there would be 700,000 fewer chronically malnourished children in the developing world by the year 2030, compared to a "business as usual" scenario. This is a measurable gain, but very small relative to the size of the problem. Under the "business as usual" scenario, there will be 134 million cases of child malnutrition in 2030, so the payoff from a 50 percent cut in meat consumption in rich countries is only a one-half of 1 percent reduction in child hunger. Reducing meat consumption in rich countries remains an excellent idea for the purpose of improving health and moderating environmental damage in those same rich countries, but not for getting more food to the hungry.

What are CAFOs?

Concentrated animal feeding operations, called CAFOs, are highly specialized industrial-scale facilities where large numbers of animals are kept in confinement for poultry, pork, beef, or dairy production. In wealthy countries, led by the United States, these systems have now largely replaced the small and diversified barnyard-style livestock systems that were once managed by individual farmers. CAFOs are a proven way to deliver higher volumes of standardized animal products to consumers at a much lower market price, yet they carry nonmarket costs and generate growing opposition from advocates for animal welfare, public health, and environmental protection.

CAFOs spread first to the poultry sector in the United States in the 1950s, then to the swine and cattle sector in the 1970s and 1980s. CAFOs are defined by the Environmental Protection Agency according to the number of animals they house. If an animal feeding operation has more than 700 mature dairy cattle, more than 1,000 cattle, or more than 30,000 laying hens or broiler chickens, it is considered a "large" CAFO and is automatically subject to regulation by the Environmental Protection Agency (EPA) under the Clean Water Act. CAFOs are spreading internationally and are now especially prevalent in China, Thailand, and Vietnam, where growth is driven by rapidly rising consumer demand for meat, poultry, and eggs. The United Nations Food and Agriculture Organization (FAO) has estimated that 80 percent of all growth in livestock production around the world now takes place within "industrial" CAFO-style systems.

Are CAFOs bad for animal welfare?

CAFOs manage farm animals under highly regulated conditions, typically in crowded confinement. Automated feed delivery and waste removal replace grazing and foraging, plus many of the traditional husbandry practices performed by human labor. This approach reduces land, labor, and facilities costs per unit of meat or milk produced, but even within the best maintained facilities, the impacts on animal welfare are problematic. The animals may face fewer risks from weather exposure and wild predators, and in some instances less harm from social conflict with each other, but they will be denied opportunities to engage in numerous instinctive behaviors—such as walking, perching, wing-flapping, or foraging—traditionally central to their daily routines. For example, in CAFOs pregnant sows weighing 400 pounds may be confined to iron "gestation crates" 7 feet long and 22 inches wide, in which they are unable to turn around. They will be on slatted floors that

make cleanup easier, but this will leave them with no bedding and nothing to root around in.

In 2005, the American Veterinary Medical Association—which has close ties to the livestock industry—convened a task force to determine whether sows were harmed by confinement, and found that the research was mixed. This does not satisfy independent advocates for animal welfare who have no doubt that the CAFO model is harmful not only to sows in crates but also to egg-laying hens in small "battery" cages. The Humane Society of the United States (HSUS) and other activist groups, such as People for Ethical Treatment of Animals (PETA), are now waging campaigns to restrict or even eliminate the use of crates and cages.

Sometimes these campaigns take the form of state-by-state ballot issues placed before voters; one early HSUS victory was a 2002 ballot measure outlawing gestation crates in Florida, followed by a 2008 measure outlawing crates plus battery cages in California. Another tactic is to confront industry directly with damaging publicity, including graphic undercover videos of injured or suffering animals. In 2012, after the HSUS released an exposé on a confinement facility that supplied pigs to meat giant Tyson Foods, a cascade of private food and food service companies announced that they would no longer be buying pork from pigs confined in crates. By October 2012, more than 30 fast food companies and food retailers had made this same pledge. Earlier in 2011, the HSUS also negotiated an agreement with the United Egg Producers (UEP) to work together to push for federal legislation to regulate treatment of birds in U.S. table egg production.

In the United States, CAFOs are regulated for human health and safety and for environmental protection, but until recently there have been few laws governing the welfare of the animals themselves, beyond those that apply to humane transport and slaughter. The United States has laws to protect companion animal welfare (the Animal Welfare Act of 1966), but farm animals were excluded, and between 1985 and 1995,

to make things worse, at least 18 states passed laws explicitly exempting agriculture from existing animal cruelty laws. Other countries have embraced higher standards. In 1991, the U.K. government required pig farmers to have their animals in pens rather than crates by 1999. Pig-producing nations in the European Union (EU) were told to have their sows in pens by 2013, and some countries like Germany went much farther, introducing in 2003 a requirement that pigs have access to sunlight, toys for amusement, and at least 20 seconds of personal contact with the farmer every day. Skeptics suspect such regulations will prove difficult to enforce.

When tighter regulations increase costs, they can risk creating sales opportunities for much less heavily regulated suppliers from places like Russia, China, and Latin America. In the United States, it costs about 27 percent more to raise pork crate-free and without the use of antibiotics or hormones for growth. Following the 1999 crate ban in the United Kingdom, the pig herd in that country declined by 40 percent. On the other hand, some animal welfare measures have proved easily affordable for consumers. When the McDonald's Corporation began insisting on larger cages for egg-laying hens, the resulting increase in cost to consumers was calculated at only about 1 penny per egg.

What else generates opposition to CAFOs?

Critics of CAFOs typically point to three concerns beyond animal welfare: microbial contamination in meat, excessive use of antibiotics, and pollution of water and air.

The microbial contamination issue centers on a charge, made in popular films such as *Food, Inc.*, that cattle fed on grain such as corn in feedlots, rather than raised exclusively on pasture, are more prone to grow a particularly dangerous strain of *E. coli* bacteria (O157:H7) in their digestive system, increasing the likelihood of meat contamination during slaughter and processing. Science does not support this claim. Grass-fed beef

is certainly more nutritious than feed-lot beef, because it has less fat, more vitamin A and E, and more omega-3 fatty acids, but there is no convincing scientific evidence that it is any less prone to O157:H7. For example, one study published in *Applied & Environmental Microbiology* in 2009 concluded, "Our study found similar prevalences of *E. coli* O157:H7 in the feces of organically and naturally raised beef cattle [on grass], and our prevalence estimates for cattle from these types of production systems are similar to those reported previously for conventionally raised feedlot cattle."

A far more genuine concern is excessive use of antibiotics in CAFO environments. The livestock industry has routinely given animals antibiotics, such as penicillin, not only to protect them from disease in crowded environments, but simply to promote weight gain. Surprisingly, 80 percent of antibiotic sales in the United States go to chickens, pigs, and cattle. This is a risk because it can speed the emergence of antibiotic-resistant strains of human pathogens. The livestock industry claims that only one-third of the antibiotics it employs are used in human medicine, but little data have been shared on how specific drugs are administered, to which animals, and why. The FDA began monitoring the presence of antibiotic-resistant bacteria in retail meat in 1996, through a National Antimicrobial Resistance Monitoring System (NARMS). The most recent report, released in 2013, indicated that over the previous decade ampicillin resistance in retail chickens had increased from 17 percent to 40 percent.

As early as 1977, the FDA had announced that it would begin banning some agricultural uses of antibiotics, but industry-friendly congressional resolutions against such bans forced the agency to back off. In 2004, the American Public Health Association adopted resolutions to restrict the use of antibiotics in meat production, but no action was taken. By 2009, according to the FDA's own figures, farmers were giving healthy animals nearly 30 million pounds of antibiotics. In Europe, such practices had been banned since 1998.

Finally, in 2012, a federal district court judge in New York ordered the FDA to ban the use of low-dose penicillin and two forms of tetracycline for weight gain purposes. As a result, the FDA initiated a three-year phase-out of antibiotic use on livestock for growth promotion purposes, and phased in a requirement for veterinary oversight of antibiotic use.

Strong opposition to CAFOs also emerges on environmental grounds. Concentrating hundreds or even thousands of animals in a confined space creates a concentrated threat to local air and water quality from the urine and manure of the animals. The resulting environmental harms may include excess nutrients in water (particularly nitrogen and phosphorus), which in turn can contribute to low levels of dissolved oxygen, leading to fish kills. Decomposing organic matter can also contribute to toxic algal blooms. CAFO systems attempt to confine the animal waste within on-site "lagoons," to be recycled later in a safe and controlled manner, but lagoon leakage can introduce pathogens into local drinking water. The EPA calculates that states with high concentrations of CAFOs experience on average 20 to 30 serious water quality problems per year. Dust and odors can lead to worker illness and respiratory problems for those living downwind from CAFOs.

In the United States, CAFOs have been regulated since 1972 under the Clean Water Act as "point sources" of pollution. A permit program sets effluent limit guidelines, and the guidelines were revised in 2003 to require that all permitted CAFOs develop nutrient management plans, but then were revised again in 2008 to require permits only for those CAFOs planning to discharge waste, a major loophole since the most environmentally damaging discharges are usually unplanned. In 1995, an eight-acre hog-waste lagoon in North Carolina burst, spilling 25 million gallons of manure into the New River, killing about 10 million fish and closing 364,000 acres of coastal wetlands to shellfishing. Two years later, a new state law was passed placing a moratorium on new construction of hog farms with more than 250 animals. Then, when Hurricane

Floyd hit North Carolina in 1999, at least five more manure lagoons burst and approximately 47 lagoons were completely flooded.

Ponds and streams in rural America have always been polluted by animal waste, but usually in a widely dispersed pattern. Thanks to the growth of CAFOs, more than half of all hog production in the United States is now concentrated in just three states: Iowa, North Carolina, and Minnesota. This can generate a far more concentrated pollution risk for nearby communities.

How important are fish as a source of food?

Fish and fishery products can be a valuable source of both protein and essential micronutrients. Fish are central to the diet in many cultures, particularly in Asia. Globally, fish provide nearly half the earth's population with roughly 20 percent of their total intake of animal protein. Fish consumption is lowest in Africa, with only 9 kilograms per person per year. In the United States, per capita consumption is more than 20 kilograms per person. Two-thirds of all fish consumption takes place in Asia, where in Japan the average annual intake is 66 kilograms per capita. Japan also has the lowest prevalence of obesity in the developed world and the longest life expectancy.

Growth in global fish consumption has been high, averaging 3.2 percent annually over the past half century. Fish used for food can either be from inland freshwater or from ocean saltwater, and are either captured or farmed. People eat not only finfish but many other water species as well, including large quantities of crustaceans such as crab; mollusks such as clams, mussels, and squid; and various other aquatic animals such as sea urchins. Traditionally, most fish consumption has been satisfied through capture (popular author Paul Greenberg has labeled fish "the last wild food"), but now roughly half the global supply comes from fish farming, referred to as aquaculture. This human move toward domesticating fish is roughly

at the same stage as our first efforts to domesticate crops and animals 10,000 years ago.

Are wild fisheries collapsing?

The total catch of marine fish peaked in 1996 at 86 million tons but then declined and has recently stabilized at roughly 80 million tons. The United Nations rates ocean fisheries as either underexploited, fully exploited, or overexploited, and since 1974, when the ratings system was created, the percentage of stocks being overexploited has increased from 10 percent to 30 percent. These overexploited fisheries are producing below their biological and ecological potential and are in serious need of improved management. An added 57 percent of stocks are close to their maximum sustainable production and have no room for expansion. In 2002, at a World Summit on Sustainable Development in South Africa, participating nations agreed on a "Johannesburg Plan" to restore overexploited stocks by 2015, but this has remained largely an empty letter. A United Nations Food and Agriculture (FAO) organization report in 2012 stated bluntly, "the state of marine fisheries is worsening." This damage to wild fisheries is a dangerous modification to a vast natural ecology, not just a threat to economic or food security.

The overexploitation of marine fisheries has technological, economic, and political origins. The technology for finding and catching fish has steadily improved. Log-Range Navigation (LORAN), Global Positioning Systems (GPS), and Geographic Information Systems (GIS) allow vessels to pinpoint the most productive fishing grounds, and recent refinements to sonar technology even allow fishers to more quickly find distinct species of fish. To locate swordfish and tuna, aircraft are deployed with infrared sensors that detect subtle changes in the surface temperature of the ocean. Airborne electronic image intensifiers also can be used to detect the light given off at night by some marine algae when disturbed by passing schools of fish.

The economic driver for overexploitation is global income growth, particularly in Asia. In China, where consumers for centuries have considered fish beneficial to the brain, income growth has fueled high demand. Between 1990 and 2009, per capita fish consumption in China increased at an average annual rate of 6 percent, reaching 32 kilograms. China's share of world fish production also grew from 7 percent to 35 percent between 1961 and 2010, and the government is now planning to expand its long-range fishing fleet by another 16 percent before the end of 2015.

The political drivers for overfishing are more subtle. National governments have come to recognize the importance of sustainable exploitation, and under the UN Convention on the Law of the Sea they terminated open access to coastal fisheries by claiming waters within 200 miles of their shores as an exclusive economic zone (EEZ). In these waters off the coast of the United States, stocks have been partly restored thanks to a 1996 law, the Magnuson-Stevens Fishery Conservation and Management Act, that set targets for rebuilding each species. As of 2013, 21 of 44 species had met the rebuilding target, and 7 others had made significant progress, increasing their populations by at least 25 percent.

Fish that migrate beyond an EEZ remain at serious risk of overexploitation. In the open ocean, restricting the catch requires international cooperation, and this has not yet been forthcoming. International concern for bluefin tuna stocks, which had declined by 75 percent, triggered a 2010 proposal to ban international trade in bluefin tuna under the Convention on International Trade in Endangered Species (CITES), but the measure was blocked by states with a strong commercial interest in the catch. Japan, which imports 80 percent of Atlantic bluefin, led the opposition, but more than 70 other countries opposed the trade ban as well. Trade bans on fish are potentially powerful instruments, since 38 percent of fishery production enters international commerce, with the European Union by itself taking 40 percent of all global imports, and with both the United States and Japan depending on imports for more than half of their domestic consumption.

Sustainable stocks management is also frustrated by fishing activities that are illegal, unreported, and unregulated, known as IUU. Many developing countries lack the physical or technical capacity to patrol their EEZ, and in some cases government officials in those countries are easily bribed into giving permits to those who overfish. Most regional fisheries are nominally governed by regional fishery bodies (RFBs), but these organizations depend too much on voluntary compliance by member governments, many of whom are unwilling or unable to exercise control. To supplement these RFBs, the United States and the European Union have been cooperating bilaterally since 2011, looking for better ways to keep IUU fish off the world market.

Is fish farming a solution?

Fish can be raised in tanks and ponds and, with the aid of cages or nets, even in oceans, lakes, and rivers. Fully "farmed" fish are those hatched from eggs within the aquaculture facility and confined for their entire life cycle, whereas "ranched" fish spend part of their lives in the wild. Some will be hatched and released, then caught when they return (like ranched salmon), while others will be caught in the wild as juveniles, then fed in confinement until they reach market weight (like ranched bluefin tuna).

The global aquaculture industry is growing rapidly, both in fresh and saltwater. In 2010, the total farm-gate value of food fish production from aquaculture was estimated at $119 billion. By volume, 89 percent of this production took place in Asia. China by itself provides 60 percent of global aquaculture production; the other major Asian producers include India, Vietnam, Indonesia, Bangladesh, and Thailand. Aquaculture production has either stagnated or contracted recently in Japan, the United States, and several European countries (with the

exception of Norway, which farms Atlantic salmon in marine cages). Two-thirds of all aquaculture species are provided with feed, which has become a significant feature of the industry.

The rapid growth of aquaculture has relieved some commercial pressure on wild fisheries, but the industry nonetheless remains controversial, often because of unsolved technical problems. Disease outbreaks have affected farmed Atlantic salmon in Chile, oysters in Europe, and marine shrimp in Asia, South America, and Africa. In 2011, a disease outbreak nearly wiped out marine shrimp farming in Mozambique.

In other cases, interactions between farmed and wild species are a concern. Wild Atlantic salmon collapsed as a commercial fishery in the 1960s. It has been replaced now by highly affordable farmed Atlantic salmon, but the farmed fish are often grown along wild salmon migration routes, posing risks such as farm-born diseases and parasites and wastes that create a pollution problem. A larger concern for carnivorous fish such as salmon and tuna is the toll taken on wild forage fish, such as herring and sardines. It requires 5–15 pounds of wild fish to grow a single pound of Atlantic bluefin tuna in a net pen, and overharvesting forage fish could bring damage to multiple commercial species.

In the United States, the fish farming industry is politically weak compared to crop and livestock farming because it is new and non-traditional. There is no national heritage of fish farming, no established cabinet agency to support fish farming, and no tradition of property rights for fish farmers. In addition, there is often strong local opposition from environmentalists plus residential and recreational users of water resources. Similar political and institutional patterns are visible in much of Europe. For these reasons, the industry is likely to continue to expand most rapidly in the developing countries of Asia. American and European consumers will become increasingly dependent on imports of farmed fish from abroad.

11

AGRIBUSINESS, SUPERMARKETS, AND FAST FOOD

What does the word "agribusiness" mean?

The term "agribusiness" was coined in 1957 by two professors at the Harvard Business School, Ray Goldberg and John H. Davis, in recognition of an important change then taking place in the American agricultural sector. The "on-farm" part of America's agricultural economy was shrinking relative to input supply industries upstream (seed, farm chemical, and machinery suppliers) and also relative to food storage, transport, processing, manufacturing, packaging, marketing, and retail industries downstream. Since farms had become just one part of a longer and more industrialized food value chain, it made sense to begin referring to the chain as a single integrated entity: agribusiness.

The new term stuck, a *Journal of Agribusiness* was founded, and soon after, more than 100 institutions of higher education in the United States began offering formal degrees in agribusiness. In 1990, the International Food and Agribusiness Management Association (IAMA) was founded as a worldwide networking organization and a bridge among multinational

agribusiness companies, researchers, educators, and government officials.

Why is agribusiness controversial?

For those inside most food and farm industries, the word "agribusiness" is used as a descriptive term with no bad connotations; in fact, it even carries a flattering connotation of modernity. Yet for critics from outside the sector, the term carries strongly negative connotations. It is deployed to suggest that traditional and trustworthy family farmers have been replaced by powerful profit-driven corporations not accountable for the damage they do to rural communities, human health, and the environment.

Critiques of American agribusiness date from 1973, when a Texas populist named Jim Hightower published a book titled *Hard Tomatoes, Hard Times*. Hightower argued that corporate power now dominated the U.S. Department of Agriculture and even the nation's agricultural universities, leading to a more rapid demise of small farms, displacing farmworkers and bringing us unhealthy food. Agribusiness firms were also a target of journalist Eric Schlosser's widely popular 1999 book *Fast Food Nation: The Dark Side of the All-American Meal*. More recently, in 2009, a popular film titled *Food, Inc.* asserted that "our nation's food supply is now controlled by a handful of corporations that often put profit ahead of consumer health, the livelihood of the American farmer, the safety of workers and our own environment."

These critics identify specific corporate villains along every separate link in the value chain. Chemical companies and multinational seed companies currently tend to attract the greatest criticism, and because the St. Louis–based Monsanto Company is both a chemical company (selling herbicides) and a multinational biotechnology company (developing and patenting genetically engineered crop seeds), it is frequently the most vilified of all. Downstream from farms, among firms

that ship and handle farm commodities, a large company from Minneapolis named Cargill is frequently criticized, both for its secrecy as a privately held firm and for its alleged market power. Within the meat sector, Tyson Foods, Inc., of Springdale, Arkansas, the world's largest processor and marketer of chicken, beef, and pork, is depicted as an enemy of small family farmers and a threat to the environment. In the packaged food sector, ConAgra Foods, Inc., of Omaha, Nebraska, is said to damage consumer health by marketing heavily processed and chemical-laden foods such as frozen dinners, Slim Jims, and Reddi-wip. Finally, at the retail and food service end, McDonald's and Burger King are accused of addicting children to unhealthy burgers, fries, and sweetened drinks. In 2012, restaurants delivered $600 billion worth of meals and service, more than the total value of all U.S. farm sales, suggesting that the American economy now generates more money serving food than it does in growing food.

Food industries have long been an inviting target for populist attack. In 1906, a muckraking novel by Upton Sinclair, titled *The Jungle*, exposed disgraceful working conditions in Chicago's meatpacking industry. Like many critics of agribusiness today, Sinclair was motivated by a suspicion toward all private corporations, and he used the emotive issue of food to dramatize these larger suspicions. The book caused a sensation, but most readers skipped over the labor rights message and focused instead on a worry that industrial meat products might not be safe to eat. Sinclair's book led directly to passage of the Meat Inspection Act and the Pure Food and Drug Act of 1906 and to the creation of a national Food and Drug Administration (FDA).

Do agribusiness firms control farmers?

Farmers in America have always worried about the market power of non-farmers. Historically, they worried most about bankers, railroads, and grain traders; today, they worry most

about concentration in the seed industry and in the meatpacking industry, where the market power of private companies vis-à-vis farmers has recently increased.

A fear of industry concentration in the international seed sector has arisen since the 1990s, following a proliferation of patent claims on genetically engineered seeds, accompanied by a rush of corporate mergers and acquisitions. Between 1985 and 2009, annual sales in global seed markets increased from $18 billion to about $44 billion. By 2008, the Monsanto Company and its subsidiaries owned more than 400 separate plant technology patents and claimed more than 20 percent of the global proprietary seed market. The top five companies had 54 percent.

On the other hand, this kind of concentration has limited reach because most countries around the world still do not allow seeds to be patented, and the vast majority do not even allow genetically engineered seeds to be planted. In addition, seed markets themselves provide only one part of the world's total seed supply. Many farmers in poor countries, and quite a few in rich countries as well, do not buy any seeds at all on a regular basis, instead planting seeds saved from their own harvest.

Within the seed markets that are proprietary, corporate concentration can be highly significant for some crops. For example, 96 percent of all genetically engineered cotton planted in the United States contains Monsanto's patented traits, and roughly 90 percent of all patented soybean traits are owned by Monsanto. Monsanto's first Roundup Ready soybean patent will expire in 2014, however—a reminder that the monopoly position provided by patents is always temporary. Companies enforce their seed patent claims in part through contracts with farmers called stewardship agreements, where farmers agree not to save and replant the seeds after harvest. The companies are also willing to go to court. According to one tally done by the Center for Food Safety in 2013, Monsanto has filed more than 140 patent infringement lawsuits over the years and has collected a total of $24 million in recorded judgments.

This does represent a new element of corporate control over farmers, but economic studies of the corn and cottonseed industries show that the patented seeds have brought cost-reducing benefits that significantly outweigh any disadvantage posed by the patent claims or greater corporate concentration. Farmers buy these seeds because the traits help them cut production costs significantly. When patent-owning companies set their prices too high, as with Monsanto's bungled introduction of a new SmartStax corn variety in 2010, farmers balk and start buying seed from another company (in this case, from an Iowa-based rival, DuPont Pioneer). In 2009, DuPont Pioneer had pressed the Obama administration to initiate antitrust action against Monsanto, but a multiyear Justice Department investigation into Monsanto was closed in 2012, without any action taken.

Market concentration in the seed sector is to some extent an artifact of the stigmatizing political attacks leveled against genetically engineered seeds (discussed in Chapter 13). Such attacks dried up European investments in this technology, leaving U.S. companies like Monsanto with few international competitors. Inside the United States, in addition, government research money could have been used to develop this technology in the public sector without patent restrictions, but Congress cut back on such funding, which gave the private sector greater dominance.

The American meatpacking sector has also become highly concentrated in recent years. By 2005, four companies controlled the processing of more than 80 percent of the country's beef; three of those same four companies, along with an additional fourth, processed over 60 percent of the country's pork. Four major companies in broiler chicken processing (including Tyson Foods) now provide more than half of the country's chicken supply. Companies such as Tyson Foods work with thousands of individual "contract chicken growers" who provide their own land and construct their own sheds to raise the chickens, while the company owns the chickens and provides all the feed.

The growers who work for agribusiness firms under this sort of contract, as well as those still struggling to survive as independents, have reason to fear that the companies will use their market power to gain a disproportionate advantage. In the 1990s, America's hog slaughter industry also moved toward greater vertical integration and concentration, a move that left even the remaining independent producers with less market control. The next worrisome step in vertical integration might take place in cattle markets. A legislative measure to bar meatpackers from owning, feeding, or controlling cattle was inserted into the Senate-passed version of the 2008 farm bill but then was dropped in conference before the bill was passed.

Outside the biotech seed sector and the livestock sector, corporations do not yet have significant market power over farmers. The largest portion of all basic crop production in the United States now comes from very large farms, but most are still family corporations (with more than half of the voting stock held by family members). Non-family corporations account for only 6 percent of all farm sales. As for control from downstream crop purchasing companies, competitive markets tend to prevail here as well, in part because concentration among the purchasing companies is offset by the countervailing power of farmer marketing cooperatives, which can be formed legally under America's federal marketing order system.

It is a stretch to imagine, as some do, that international corporations control the lives of poor farmers in the developing world. Most poor farmers in Africa do not make any purchases of seeds at all (they save seeds from the previous season's crop), and they make only minimal purchases of fertilizers and pesticides. When they do market a portion of their crop, it is usually to local buyers or to government-regulated marketing boards, rather than to vertically integrated agribusiness firms. Private international companies are not interested in most African farmers because they lack the purchasing power to be good customers. In Africa, only 2 percent of all investment in agricultural research comes from private firms. The danger is less that international investors will control poor farmers in Africa, and more that they will continue to ignore them.

Do food companies and supermarkets control consumers?

Critics suspect that agribusiness firms, including retail supermarket chains, exploit their market power to raise the cost of food to consumers. When food prices rose sharply in the United States in the 1970s, Jim Hightower (of *Hard Tomatoes* fame) alleged that without the monopoly power of agribusiness, food would have been 25 percent cheaper for the American consumer. Careful studies by economists show that monopoly power in the food manufacturing industry does raise costs to consumers, but not by a large percentage. Bruce Gardner, a leading American agricultural economist, calculated that in the 1990s only about 2 percent of the consumer's final marketing bill went to pay for "excess profits" due to imperfect market competition.

With respect to supermarkets, studies show that the industry has become more concentrated, and in cities with fewer competing stores, consumer food prices are indeed higher. Yet the rate of profit in the retail food industry overall, measured per dollar of sales, has not increased over time, thanks to the efficiencies from larger store size that are passed on to consumers. A study by the U.S. Department of Agriculture's Economic Research Service in 1989 found no significant effect on supermarket prices from increasing industry concentration. A review by the Federal Trade Commission in 1990 found the same. Instead of controlling consumers, modern supermarkets compete with each other to attract customers by offering an ever growing array of affordable food purchase options.

Some food companies have clearly held near-monopoly positions for individual food products. For example, General Foods has enjoyed nearly 90 percent of the market in Jell-O-like products. Yet there is no convincing evidence that the

company's profits from Jell-O have been higher than for products such as peanut butter, where there is much more competition. If profits begin to move up, competitors will move in, as in the case of the creatively blended ice cream sold by Ben & Jerry's, which became so successful that it quickly inspired competing alternative brands. The American food industry has roughly 300,000 individual firms overall, more than enough to provide competition. In the 1970s, the Federal Trade Commission looked at charges that the three largest breakfast cereal companies (Kellogg's, General Foods, and General Mills, which together had 80 percent of the market) were engaged in predatory behavior by proliferating their own brands to monopolize store shelf space. But, after a 10-year investigation, the case was dropped. In subsequent years, the market share of these top three companies fell in any case, as new private-label companies moved into the sector.

Are supermarkets spreading into developing countries?

Supermarkets are pervasive in rich countries, and they now are spreading rapidly into the developing world, bringing more choices for consumers but uncertain consequences for competing retailers and local food producers.

Supermarkets tend to spring up naturally wherever people have increased incomes and refrigerators, wherever women have entered the workforce, and wherever automobile ownership has begun to spread. North America, Europe, and Japan have fit this profile for decades. In France today, just as in the United States, 70–80 percent of national food retail sales are made in supermarkets. More surprising has been the recent and rapid spread of supermarkets into parts of the developing world where affluence, auto ownership, and female workforce participation are not yet as fully developed.

In Latin America, only 10 percent of all food retail sales were made through supermarkets as recently as the 1980s, but by 2000, that figure rose to 50–60 percent. Supermarkets took

off five to seven years later in East Asia and Southeast Asia and then exhibited even faster growth. In Taiwan and South Korea, supermarket sales quickly gained a 63 percent share of all food sales. In China, as recently as 1991, there were no supermarkets at all, yet by 2001, the supermarket share in Chinese urban food markets was 48 percent. Supermarkets do not yet serve as many customers in South Asia or in Sub-Saharan Africa. For example, retail market shares in India and in Nigeria have recently reached only 5 percent.

One key factor in the spread of supermarkets in poor countries has been electrification and the availability of home refrigerators, which make possible the purchase of fresh foods in larger quantity on a less frequent basis. Second has been the opening of more national economies in the developing world to foreign direct investment, particularly since the 1990s. This gave established supermarket chains, such as Ahold, Carrefour, Tesco, and Wal-Mart, opportunities to move quickly into the retail food markets of Latin America and Asia. Three of every ten pesos spent on food in Mexico today is spent at a Wal-Mart.

Local consumers generally benefit when supermarkets arrive, because they gain access to a wider variety of food purchase options offered at a higher standard for both food safety and cosmetic appearance, and usually at a lower cost. Some local farmers and local food wholesale and retail competitors will be threatened, however.

Traditional local farmers usually cannot provide the steady supply of top-quality fresh food that a multinational supermarket will require, because of inferior harvest techniques and lack of post-harvest product protection, resulting in lower-quality produce. As a consequence, traditional local farmers tend to be bypassed by supermarket buyers, who purchase instead from modern-style specialty farms, often created through still more foreign investment. These farms deliver contracted produce either to the supermarket directly or, more likely, to yet another new commercial institution, a distribution center that will serve as supplier to multiple local supermarkets. Systems

of this kind bypass both traditional local farms and traditional urban wholesale markets. The rapid insertion of these exotic systems into food markets in the developing world changes the diet of consumers (encouraging the consumption of more packaged foods, processed foods, and internationally branded imported foods) and it also changes the market position of local food producers and wholesalers, keeping them away from the most affluent local customer base.

Is Wal-Mart taking over food retailing in Africa and India?

Wal-Mart is the world's largest retailer (of much more than just food). It is the largest private employer in the world, with 10,000 stores in 27 different countries, under nearly 70 different names. Wal-Mart's data-mining capacity is second only to that of the Pentagon. Until recently, supermarkets like Wal-Mart had a relatively small footprint both in Africa (where income growth is still lagging) and in India (mostly because the government of India did not allow foreign retailers majority ownership in "multi-brand" stores). Then, in 2011, Wal-Mart decided to invest in Africa, purchasing for $2.4 billion a majority share in the South African retail chain Massmart, which operated 290 stores in 13 African countries. Wal-Mart had earlier lost out in Asia to fast-moving rivals like Tesco and did not want this to happen in Africa.

Gaining access to the Indian market remained more difficult. In 2011 the Indian Cabinet approved a plan to permit foreign retailers majority ownership, but then pulled back for a year in the face of strong opposition from small traders and shopkeepers who feared they would be put out of business. But when India's economic growth began slowing in 2012, the government revived its plan to attract more foreign investment into the retail sector, and the president of Wal-Mart's Indian unit responded by promising to come in as a good citizen, investing to help build the infrastructure that India needs to lower retail costs and reduce post-harvest waste. Critics and

opposition party leaders knew that Wal-Mart was being investigated for earlier paying millions of dollars in bribes to local officials in Mexico when it expanded its operations there, and they warned that the same aggressive approach would be used to corrupt officials in India. Paying bribes ("speed money") to local officials is often the only way to make things happen in India, where in some states retail chains must secure 50 to 60 separate regulatory approvals before they can open a store. But an international investor like Wal-Mart will come under a higher level of scrutiny if it follows this path.

Are fast food restaurant chains spreading unhealthy eating habits worldwide?

Unhealthy eating styles are spreading globally. According to one 2012 estimate, three decades from now, if current trends continue, people in today's low- and middle-income countries will be consuming as much unhealthy food as people today in rich countries. Increased consumption of packaged foods, snack foods, and soft drinks purchased from supermarkets will be part of this trend, but increased patronage at fast food ("quick-service") restaurant chains will contribute as well.

Quick-service chains went global in the 1980s and 1990s, moving into many countries alongside supermarkets and at an equally rapid rate. In 1990, South Korea had four McDonald's restaurants; five years later, it had 48. In the same short five-year period, China went from having one McDonald's restaurant to 62. Indonesia went from none to 38. Brazil went from 63 to 243. During this high-growth period, a new McDonald's restaurant was opening somewhere in the world every three hours. Critics see this as an unfortunate imposition of bad food—as well as America's most garish commercial culture—onto new urbanites in the developing world, who are naively enthralled at becoming more "Western."

As usual, the picture is more complicated. Quick-service "street food" for urbanites pre-dated the arrival of McDonald's

restaurants. In Asia, takeaway stands selling salty fried foods have long been a not-so-healthy option. In South Asia, street foods abound, for example *panipuri*, which is fried bread with a spice and potato filling. In the Middle East, flatbread and falafel to go are found everywhere. In urban West Africa, ready-to-eat char-grilled meat sticks have long been popular. To some extent, Western fast foods are merely a replacement for these traditional local fast foods, many of which also fall short of providing a balanced diet.

On the issue of cultural imperialism, anthropologists who study the impact of fast food restaurants in developing countries have found a mixed result. In many East Asian settings, fast food restaurants do not replace traditional cuisine because they are often a place to go for a snack between meals, or to socialize with friends after school. Asian customers view fast food chains as distinctly modern but not always foreign. In China, McDonald's restaurants are 50 percent Chinese owned, nearly all are Chinese managed, and 95 percent of the food sold is sourced from China. Surveys reveal that a majority of the young customers even believe that Ronald McDonald is Chinese and lives in Beijing. Instead of changing China's family-oriented food culture, McDonald's makes money by catering to it. Entire families are welcomed for parties and celebrations, with paper and pen provided for young children to write and draw. Teahouses and art galleries are common features as well. Customers were initially attracted to fast food restaurants in China because they had clean toilets, a benefit that competing local restaurants soon had to provide as well.

The chains that do best are those that follow local dietary preferences. KFC outsells McDonald's in China because chicken is more of a staple in the traditional Chinese diet than beef. Subway offers kosher food in Israel, nearly all of their restaurants in Muslim countries are *halal*, and beef-free, pork-free, and vegetarian products are offered in India. McDonald's has also enjoyed rapid growth in India, with 250 restaurants in 2011 and plans to double that number by 2014. In Hindu India, where cows are revered, beef has been taken off the menu and replaced by vegetable patties and giant Maharaja Macs made with chicken.

In countries such as China and India, it is the rise of an urban middle class that has done the most to alter traditional eating practices. Multinational supermarkets and fast food chains expand to make money as soon as this underlying shift begins, and they even speed it along and shape it in a Western direction, but urbanization and income growth would have changed eating patterns in these countries even without supermarkets or Western fast food.