



Today's Food System: How Healthy Is It?

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With its focus on the quantity of production, often to the exclusion of other goals, today's food system is on an unsustainable course. The problem begins with and is driven by industrialized production of both crops and animals. Industrialization is a product of technological change, public policy, and, most recently, globalized trade. The lack of sustainability derives from reliance on the intensive use of nonrenewable and hard-to-renew resources—soil, antibiotics, fresh water, and fossil fuels, for example—but also from the waste and pollution created by the industrial model. For at least 50 years, American agriculture policies have promoted production of, and ultimately lower market prices for, commodity crops like corn, wheat, and soybeans. Over the last 3 decades in particular, these “cheap food” policies have exacerbated the negative impacts of an industrialized agriculture on the health of the agro-ecosystem, as well as on the health of the humans who must share and be sustained by it. Sustainability and health are two sides of the same food system coin. Policies that put US food production on more sustainable footing can help aid in public efforts to address the myriad crises confronting both the food and health systems.

KEYWORDS food systems, industrialization, systems thinking, agriculture policy, ecological public health

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INTRODUCTION

There is a sense of crisis around the nation's health, as there is around food.

On one side is the epidemic of obesity–diabetes (among other rising chronic diseases) and the huge future costs they portend. Medical costs of obesity in the United States are estimated as \$147 billion annually, and climbing¹; combined with other diet-related chronic disease (cancer, cardiovascular disease, stroke, and diabetes), that figure could be as much as 5 times higher.²

On the other side are outbreaks of foodborne illness, food contamination scares, volatile food prices, and “food deserts,” not to mention drought and water shortages, soil depletion, climate change, fishery collapse and other events with significant—albeit less direct—impacts on nutrition and health. Clearly, both food and health systems are under stress. How might the two be related?

Figure 1 combines trend data on food spending from the US Dept of Agriculture³ with health spending data from the Organization for Economic Co-operation and Development (OECD).⁴ The contrast is striking. From 1970 to 2003, Americans' per capita health care spending *increased* from \$353 to \$5711 annually, whereas real median household income increased from about \$41,000 to just over \$50,000 from 1970 to 2007.⁵ Barring policy change, the trend for health care spending is steeply upward. At the same time, Americans spend fewer total dollars on food as a percentage of

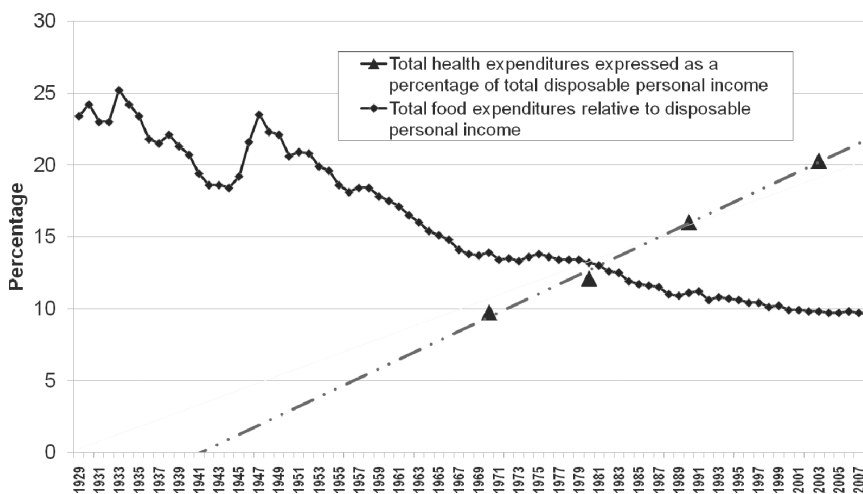


FIGURE 1 American spending on food, health relative to disposable income.

Sources: 1) USDA Briefing Room. Food Expenditures by Families and Individuals as a Share of Disposable Personal Income. Economic Research Service. Accessed 18 March 2009 at www.ers.usda.gov/briefing/CPIFoodAndExpenditures/Data/table7.htm; 2) Kaiser Family Foundation Health Care Spending in the United States and OECD Countries, January 2007 Accessed 18 March 2009 at www.kff.org/insurance/snapshot/chcm010307oth.cfm

disposable income than ever before. In 1930, for example, it was about 24%. Today, it is just 9.6%, about a third lower than the 14% figure for 1970.³

There may be no direct association between the two trends. Engel's law, from the field of agricultural development, states that as incomes grow the share of household income spent on food will decline, and the United States as a nation has certainly grown wealthier since 1970.⁶ Putting food and health spending trends side by side, however, does raise a provocative and worthwhile question. How much health do America's food dollars buy?

To get a deeper and broader understanding of the health of the American food supply, this essay looks beyond retail food prices to the entire "food system." (The food system encompasses not only the production of food but its harvest, processing, distribution, and marketing as well; increasingly, the American food system cannot be considered separately from the larger global context in which it plays such a major role.) Focusing on the food production portion of the food system, the essay highlights and offers exemplars of the interconnectedness of food, agriculture, the environment, and health. The essay first reviews how industrialization, technology, and other economic forces, like globalization, have shaped the food system. A holistic or integrated discussion follows of the impacts of this transformation on both human and ecosystem health. The third section puts this information in the context of US farm and food policy and its changes over the last 80 years. The essay concludes that concerns about the health and sustainability of the food system are closely linked. Food, after all, is sustenance. Our bodies cannot do without it. Beyond that, what farmers produce and how they produce it impacts on *health* regardless of how narrowly or broadly one defines that term; food production affects nutrition, public health, the social health of rural communities, and the health of agro-ecosystems. Conversely, if our current food system undercuts the long-term ability of food-producing lands and waters to remain resilient and productive in the face of climate change, population growth, and other major challenges—as many longtime observers now fear—then how healthy is that?

INDUSTRIALIZATION, TECHNOLOGY, AND GLOBALIZATION

Prior to the late 1950s, farms in the upper Midwest, the American "Corn Belt," grew row crops like corn and soybeans but only on about half the farmland, where it was interspersed with other small grains, hay, and pasture. Grain, hay, and pasture on the farm typically were not commoditized or sold but were fed to one or more kinds of animals on the same farm.⁷ It was a type of food production system where the farming and the health of the ecosystem were closely linked and environmental degradation was uncommon, as Altieri and Nicholls⁸ have described:

[C]rop yields in agricultural systems depended on internal resources, recycling of organic matter, built-in biological control mechanisms and rainfall patterns. Agricultural yields were modest, but stable. Production was safeguarded by growing more than one crop or variety in space and time in a field as insurance against pest outbreaks or severe weather. Inputs of nitrogen were gained by rotating major field crops with legumes. In turn rotations suppressed insects, weeds and diseases by effectively breaking the life cycles of these pests. (p. 13).

The farm family lived there on the farm and performed most of the labor themselves with little or no hired help or specialized machinery.⁸ They too were an integral part of the agro-ecosystem; their health and well-being were intimately tied to it. That typical integrated Midwestern farm of a few decades ago is well on its way to extinction.

What Is Meant by Industrialization?

Over the last 150 years, industrialization slowly transformed American agriculture, including the mindset of farmers (Figure 2). New technologies have been one important driver of industrialization: the advent of cheap, abundant fossil fuels; the innovation of new higher-yielding plant and animal breeds; farm mechanization; and changes in railroads, highways, and other transportation infrastructure, as well as in refrigeration, making it easier to ship agricultural products to distant points. Industrialization has transformed American agriculture from a local, smaller-scale enterprise where most of the needs of the farm were met by on-farm resources into a much more specialized enterprise, one consolidated into ever fewer and more massive farms, where off-farm resources such as fossil fuel energy, pesticides, and fertilizers are used intensively. Specialization means that whereas the typical American farm once produced many different things (e.g., corn, oats, wheat, chickens, hogs, cows, milk, etc.), including both crops and animals, it now produces just one or two commodities, and

Perspective: The farm as a factory with “outputs” (corn, soy, animals) and “inputs”

(feed, fertilizer, pesticides, antibiotics)

Features:

- Specialization, monocultures
- Reliance on off-farm resources (energy, chemical and other "inputs")
- Delinked animal and plant agriculture

FIGURE 2 Industrialized agriculture—perspective and features.

Source: Union of Concerned Scientists

crop production has been “delinked” from the raising of food animals to which most grains and other grasses on the farm used to be fed.

The specialization, scale, and resource intensiveness of industrialized agriculture all impact on human and ecosystem health in ways that are best appreciated from a systems perspective. For example, the delinking of crop from animal production has rendered infeasible a number of practices that historically provided important services adding to the health and resilience of the food production system. Rotation of corn with soybeans or other nitrogen-fixing crops helped replenish soil nitrogen; the growing of multiple crops (“multicropping”) also helped to suppress the lifecycles of pests and disease.⁸ Animals once provided cheap horsepower for crop production, and animal manure plus crop refuse (corn stover, etc.) in turn was recycled to restore organic matter and fertility into soil as part of a low-cost, closed-loop system. Soils high in organic content can sequester more carbon, better resist erosion, and help retain more rainwater, making them more resilient during drought. Indirect impacts of the loss of these ecosystem functions on human health are discussed in the following section.

Over the last 5 decades especially, the changes begun under the initial industrialization of agriculture crystallized into what Lang and Heasman have termed a *productionist* mindset—placing short-term quantity or yield over all other priorities. This has become the dominant 20th-century outlook for the food system not only in the United States but globally.⁹

What Does Agricultural Industrialization Look Like?

Under industrialized or productionist agriculture, rural farm landscapes have transformed in appearance; once diverse landscapes, agro-ecosystems comprised of mixtures of crops, animals, pastures and woodlots, have given way to “monocultures”—ever-larger homogeneous farms, specializing in a single commodity. In ecological and economic terms as well, this transformation has been dramatic. In some counties in the heart of the Corn Belt over 90% of farmland is planted in corn or soybeans⁷ and increasingly in just corn. Moderately sized Iowa farms (100 to 500 acres) are disappearing¹⁰; of the farms that remain, 60% are larger than 1000 acres.⁷

Economies of scale in the production of single commodities, or monocultures, helped precipitate the trend toward larger farms, with more acres under till.⁷ Ever larger machinery meant that greater acreage in corn and soybeans could be planted and then harvested in very narrow calendar windows, sparing labor.¹¹ Specially designed seed varieties plus the use of insecticides made it possible in the short term to grow only corn, year after year, without significant yield consequences. Herbicide-tolerant soybean breeds also have reduced the summer hours previously needed to “walk the beans” for the control of weeds.

Since Corn Belt farms are increasingly devoted to monocultures of single crops, crop farmers have no animals to tend, and the help of machinery,

fuels, and new seeds means less time than ever is required to plant, weed, and harvest their huge acreage. As a result, today's crop farmer has few reasons to be on the farm for most of the year. Second jobs are typical. From within the industrial agricultural economic model, these changes typically are perceived as gains in efficiency.

Bigger machines and chemical-intensive production has made farming much more capital intensive, however. An estimated half a million dollars in capital are required to support a farm today, raising a significant economic barrier for the entry of new farmers.¹² With more than 60% of farm operators 55 years of age or older in 1997, this looms as an important issue.

In addition, because crop farmers are now delinked from the animal-related fertilizer and recycling practices that previously added health and resilience to on-farm systems, they have turned instead to off-farm resources or "inputs." Along with specialization, the intensive use of these inputs is a hallmark of industrialized production. Moving from horses or oxen to mechanized tractors, farmers traded farm "tools" that could be fed on forage to ones fed only on fossil fuels. Crop monocultures, made possible by the use of hybrid seed varieties fertilized with inorganic off-farm, natural gas-derived fertilizers, have replaced diverse multicropping systems that were fertilized by on-farm manure or other organic residues. Crop monocultures, however, also encourage pest outbreaks by concentrating the opportunities for pests (rodent, insect, and weed) of these crops to thrive while also undermining the integrated ecosystems that might play host to the natural enemies of these pests.¹² The new plant hybrids, like "Roundup Ready" corn or soybeans, therefore have been specially designed to tolerate heavy applications of herbicides without being killed themselves. The patented seeds, which must be purchased annually from off-farm, in some cases replace seeds collected on-farm for free by the farmer. The herbicides too are derived from off-farm petroleum.

Movement of animals off-farm has made the on-farm use of organic manure impractical or uneconomic or both. What has been lost is more than just an inexpensive, on-farm source of fertility. Over the past few decades, crop farmers who had animal barns or fences remaining on their property came to see them as unproductive assets and got rid of them. Now, nondiversified crop farmers can no longer "hedge their bets" when grain crops fail or the prices are low, by raising and selling animal products—their production model is more vulnerable by virtue of its lack of diversification. As will be discussed, public policy has encouraged this transformation.

Moving the discussion from crop to food animal production, the increased specialization in industrialized agriculture also has meant that animal operations focus on producing just one species, and increasingly, one age range for that animal; for example, facilities devoted to only small, "weaner" pigs that are later shipped to other facilities for maturing to slaughter size. Larger-scale production means hundreds or thousands of

hogs or poultry typically are confined indoors in a single building, with many such facilities clustered spatially and often regionally. Large animal numbers mean large quantities of manure waste are generated and concentrated in these areas as well.

Off-farm resources used intensively by these industrialized animal facilities include feed grains, water and energy, as well as antibiotics and other feed additives. The poultry and hog industries are the most industrialized. The most delinked from pasture-based production, they are the systems most based on indoor confinement of animals and therefore on feeding animals a diet of feed grains rather than of crop residues or the other by-products on which animal production had previously relied. The poultry and hog industries consume over 75% of cereal and oilseed-based concentrated animal feeds, worldwide.¹³ Corn and soybeans constitute 83% to 91% of these feed grains, and so 55% to 65% of the US corn crop and 45% to 50% of its soybeans are consumed by domestic livestock and poultry.¹⁴

Lacking the associated cropland to spread manure as fertilizer, large-scale industrial livestock producers have found few alternatives other than to waste it. The manure cannot be economically transported for any distance. It therefore is often disposed of in ways that lead to nutrient runoff and pollution of surface and/or groundwater resources. USDA data demonstrate that the largest industrial hog operations tend to be those with the most manure pollution problems; that is, where manure is disposed of as waste product rather than a productive resource.¹⁵

Industrialization of the food system, it is important to note, has been happening globally. Further, industrialization has occurred all along the food supply chain, as processors acquired the capacity to preserve, store, and distribute huge volumes of food. Over recent decades, these food processors grew both horizontally (by buying competitors) and vertically (by buying their own suppliers and distributors), leading to market concentration. Eventually, this growth gave rise to increasingly global trade of grains, meat, and other food products, which in turn became another driver in the further industrialization of the food system. US trade "liberalization" policies in food have had the effect of reinforcing these patterns.

Globalization of the food system has had impacts on patterns of resource use and pollution, as well as on social health.^{9,16} Power in the food system is shifting from the production end to food processors and retailers that operate globally, and this has important health implications as well.¹⁶ For example, contractual agreements increasingly bind the financial interests of farmers to the interests of both the buyers of their output and the suppliers of their inputs.¹² By 1997, just 163,000 farms accounted for over 61% of total American farm production, and 63% of those produced a single agricultural commodity under contract to consolidated firms, often global in nature.¹⁰

IMPACTS OF INDUSTRIALIZATION ON HUMAN AND AGRO-ECOSYSTEM HEALTH

Food production, human health and welfare, and the state of the world's natural resources are inherently connected. "Growing food is among the most essential services our ecosystem provides, since it is fundamentally dependent on the world's atmosphere, soils, freshwater and genetic resources," according to Rosamond Naylor of Stanford University.⁶ More simply, people need food to survive and thrive. The health and sustainability of the America's agro-eco food system *is* a human health issue, therefore. Yet a number of leading experts in systems biology, agro-ecology, and public health now question that sustainability.^{6,8,12,17-19}

That hallmark of industrialized agriculture, the intensive use of resources, is at issue. The unsustainable rate of use of renewable resources, like groundwater and soil, is one dimension. The intensive use of nonrenewable resources, especially including fossil fuels but also pesticides and antibiotics, is another.¹⁹ A third issue is that intensive resource use, when combined with the lack of natural cycles to reuse these resources on the farm, creates wastes that not only pollute air, soil, and water quality but also pose health risks to the people relying upon them. Risks to human health can be acute in nature, such as the risk of pesticide poisoning. More often, they are longer-term risks experienced by populations downstream or remote in time compared to when the pollution first occurred. The pollution of groundwater resources with nitrogen, the development of environmental reservoirs of antibiotic resistance, and climate change fall into this category. The following section describes a few of these problems in greater detail and begins to make some of the links between them, as well as offering examples of the interconnectivity of health and agro-ecological sustainability.

Water

In its 2000 National Water Quality Inventory, the Environmental Protection Agency (EPA) identified agriculture as a pollution source in 48% of polluted river and stream waters (which comprised 39% of all US rivers and streams assessed for water quality) and in 41% of polluted lakes (nearly half of all US lakes assessed).²⁰ Industrialized farming practices are largely to blame because they contribute disproportionately to silt and to the runoff into water bodies of pesticides, fertilizers, and other chemicals and of nitrogen and phosphorous in animal wastes.¹⁹

Airborne pesticides can drift onto water resources, for example, or pesticides can run off directly from croplands into groundwater and surface waters, potentially affecting wild flora, fauna, and humans. Potential health impacts of agricultural pesticides are discussed later; pesticide contamination

of municipal drinking water systems also increases water treatment costs. Excess nitrogen in surface waters can impair aquatic ecosystems; nitrogen runoff into the Upper Mississippi River from the Corn Belt, for example, is considered one of the major causes of the sizeable dead zone in the Gulf of Mexico, where nutrient-fueled algal growth ultimately creates a sea “so depleted of oxygen that fish, shellfish, and other aquatic life cannot survive there.”²¹(p. A242) In the human gastrointestinal tract, the nitrates in drinking water may be converted into nitrite, which can cause “blue baby syndrome” (methemoglobinemia) in infants; they also have been associated with higher risks of miscarriage and some cancers, including cancers of the bladder, ovaries, and non-Hodgkin’s lymphoma.²²

Besides pollution, production agriculture reduces the amount of fresh water available for other, nonagricultural purposes, which will become increasingly problematic as climate change and population growth place additional demands on limited water resources. Crop production alone accounts for around 80% of all fresh water used in the United States for any purpose.²³ Corn is a particularly thirsty crop. Irrigation occurs on roughly 15% of corn acreage, consuming energy as well as limited water resources. Most irrigated corn draws its water from the Ogallala Aquifer, the largest groundwater resource in the United States, which also provides drinking water to some 2 million Americans.¹³ By 1980, overdrafts of the Ogallala had led in some parts of Kansas, New Mexico, Texas, and Oklahoma, to local declines in groundwater levels of more than 100 feet; between 1980 and 1999, groundwater levels dropped another 40 feet to more than 60 feet in several areas of the same region.²⁴ Further water level drops could render irrigation prohibitively expensive in this important production area for wheat, corn, and other crops.

As discussed, the majority of US corn and soybeans is fed to animals as feed grains. In fact, feed grain production accounts for nearly all the water and the majority of the nitrogen resources “consumed” by US food animal production. About 20% more irrigation water in the United States—an estimated 20 km³ per year—is for feed grains destined for export rather than for use in producing meat consumed by Americans.²⁵ “Through its corn exports,” note Galloway et al, “the U.S. is rapidly depleting a scarce environmental resource and exacerbating water conflicts, while not being fully compensated for its loss.”¹³(p. 626)

Soil

Besides water, soil is another critical basis for long-term fertility in food production. Existing agricultural practices mine soils of their organic matter and leave them nitrogen depleted. One quarter to one third of US soil is estimated to have been lost over the last 200 years; soil erosion is most associated with the annual production of cereal grains: corn, wheat, rice,

oats, etc.¹⁸ Under preindustrial agricultural conditions, it is estimated to have taken 200 to 1000 years to gain 2.5 cm of new soil.²⁶ USDA data from 1997 indicate instead that every 34 years US agriculture is losing an amount of soil equivalent to a 2.5-cm-deep layer spread over every acre of cropland in use.¹² Wes Jackson points out the irony that spectacular gains in agricultural yields over the last 100 years have come in no small part due to the virgin soil “wealth” handed to America’s farmers; that resource wealth is now being spent down, making future gains in crop yields less and less likely.¹⁸

Nonrenewable resources used intensively in industrialized agriculture include pesticides, fertilizers, fossil fuels, and antibiotics. Because industrialized agriculture generally lacks practices to sustainably cycle these resources within the production system, they often become wastes that further undercut human and agro-ecosystem health.

Pesticides

The degraded soils and monocultures typical of industrialized agriculture can lack an intact ecosystem’s natural resilience to suppress disease and pests. Compensatory practices therefore have included the widespread use of pesticides, largely derived from petroleum. US insecticide use increased 10-fold from 1940 to 1989, for example, although application rates may have declined slightly since then.²⁷ In addition, the widespread adoption in industrialized agriculture of pesticide-tolerant plant hybrids, such as “Roundup Ready” corn and soybeans, has led to an estimated 50 million more pounds of pesticides used in their first 8 years.²⁸ Pesticide use in general has translated into the routine exposure of American consumers at low levels to a complex, untested mixture of multiple pesticides²⁹; the typical diet of conventionally raised fruits and vegetables can be expected to carry multiple pesticide residues.³⁰

Pesticides are designed to be toxic, and “nontarget” organisms like native plants, wildlife, and humans often are harmed along with pests. Many pesticides can weaken animals’ immune systems, including in frogs and honeybees, leaving them less protected against natural stressors or infection^{31,32}; honeybees are essential pollinators for \$10 billion worth of US crops, yet pesticides likely have contributed to a crisis in dropping numbers of honeybee colonies.³² With around 900 chemical ingredients EPA registered as pesticides, however, it can be difficult to generalize about human toxicity to the entire group. Moreover, surveillance of human populations for impacts from agricultural pesticide use has been infrequent and limited in scope. One non-annual report from the independent Poison Control Centers (PCCs), however, indicated that agricultural pesticides resulted in at least 58,000 unintentional human poisonings in 2002.³³ One physician group’s comprehensive scientific review has found that pesticide exposures likely contribute to a number of chronic diseases, including several kinds of

cancer and adult neurological diseases including Parkinson's; children have been found especially vulnerable to similar problems.³⁴ In the last 2 years, studies conducted using data from 89,000 Americans enrolled in the Agricultural Health Study also have associated exposure to certain pesticides with heightened risks for pancreatic cancer,³⁵ bladder cancer,³⁶ colon or rectal cancer,^{36,37} and diabetes.³⁸ It is chronic diseases, typically with multiple cofactors, that now drive most illness and health care costs among Americans.

Nitrogen

When crop and food animal farming were more closely linked, farmers routinely used the nitrogen and phosphorus nutrients in animal manure, applied to land at appropriate rates, to help renourish and fertilize soil and the crops subsequently grown on it. When nutrient levels in soil are not too high and sufficient organic matter is present in soil, for example, soil bacteria can immobilize manure nitrogen by converting it into nitrates to be later taken up by nitrogen-needing plants, like corn.

By contrast, farmers producing monocrops intensively (and without animal manure) try and compensate for a loss of soil fertility by relying on the use of chemical fertilizers. US agriculture in 2007 used nearly 23 million tons of chemical fertilizers, of which about 58% were nitrogen based. In effect, using the 80-year-old Haber-Bosch process, manufacturers convert the fossil carbon contained in natural gas into a feedstock for fixing atmospheric nitrogen and then applying it to the land; roughly 1% of the world's total energy consumption is devoted each year to making about 100 million tons of synthetic nitrogen fertilizer in this way.³⁹ Of synthetic nitrogen fertilizers used in the United States, around 43% are applied to the corn crop.⁴⁰ Only about one third to one half of the applied nitrogen is absorbed by plants themselves⁴¹; much of the remainder is "lost" to soil, air, or water. Longer term, these practices undercut sustainability because they deprive the soil of carbon in manure or crop residues that would otherwise be tilled in, resulting in a net loss to the soil's native organic matter.⁴²

The impact on ground and surface water quality of excess nitrogen applied to croplands has been discussed. Groundwater contamination with nitrates is a costly public health problem, as well; more municipal drinking water supplies have been closed for violating nitrate standards than for any other contaminant.⁴³ Excess nitrogen in soils, too, can impair soil fertility and reduce plant diversity and biomass production.¹⁹

Nitrogen-intensive crop production also translates into nitrogen waste issues in livestock production. The nitrogen fertilizers used on crops destined for animal feed globally represent about 40% of the manufactured total.¹³ From another perspective, feed grain production represents 70% of the consumed nitrogen in industrial animal production.²⁵ Most of the nitrogen concentrated in these animals via feed grains is then lost to the environment,

where it becomes a significant environmental waste problem. In 2003, industrial operations raising livestock or poultry on feed grains accounted for around a half a billion tons of untreated manure, the sheer quantity of which is too great to be responsibly applied to available lands.¹⁵ The largest and most industrial of such facilities, called CAFOs (concentrated animal feeding operations), produced more than half the manure.⁴⁴ At the same time, because industrialized crop production often leaves cropland deficient in soil organic matter, it can diminish the land's inherent capacity to absorb and immobilize the manure nitrogen applied there. The "excess" nitrate-nitrogen from this manure is thereby more available to leach into surface waters or groundwater or, alternatively, to get converted by soil bacteria into atmospheric nitrogen gas, nitrous oxide, and nitrogen dioxide.⁴³

Nitrous oxide from manure is a potent greenhouse gas, as is discussed below. (Further upstream, nitrogen and carbon contributing to climate change also are emitted during the production and use of nitrogen fertilizers on crops, before they become feed grains and, ultimately, animal waste.) Ammonia from manure also volatilizes and can deposit nitrogen onto soils closer to livestock facilities, causing soil acidification. Ammonia also can irritate the human respiratory tract and lungs.

Carbon

Like other resources, the American industrial food system consumes fossil fuels intensively, accounting for about 19% of the nation's fossil energy use.⁴⁵ Of this, around 7% is consumed by agricultural production, with greenhouse gas emissions (2001) of 474.9 million tons of carbon dioxide equivalents (the rest is for food processing and packaging, distribution, and food preparation by consumers).⁴⁶ Pimental estimates that per capita energy use in the United States for the food system alone is more than twice the total energy use per capita in Asia and 4 times per capita energy use in Africa.

Monocrop production relies on fossil fuels to run the machinery used to plant, fertilize, and harvest huge numbers of acres within tight time windows; fossil carbon is embedded in natural gas-derived fertilizers and petroleum-derived pesticides as well. The average US farm uses 3 kcal of energy to create 1 kcal of food energy.¹⁹

Fossil fuel consumption is just as integral to industrial meat production. The average American gets 67% of protein from animal sources, nearly twice the global average.⁴⁵ Global meat demand also has risen 75% over the last two decades, driven by rising population and incomes; more and more meat trade is expected to meet this demand, with a 50% increase anticipated over the next quarter century.²⁵ Whereas plants can utilize sun energy, animals are much less efficient at converting energy into food. For example, chickens require 2 kg of feed grains to produce 1 kg of meat; grain-to-meat conversion for pork and beef is 4:1 and 7:1, respectively.¹⁹ The resource

cost to produce meat therefore is higher and reflects the substantial resources consumed in the production of the grains fed to them. The delinking of animal and crop production, combined with the shift of animals from forage or by-products to feed grains, is what makes these trends so significant for fossil fuel consumption and for climate change.

As detailed by the Food and Agricultural Organization (FAO) of the United Nations, food animal production is an important source of carbon dioxide (CO₂), methane (CH₃), as well as nitrous oxide (NO₂) emissions—all are important as air pollutants and as greenhouse gases.⁴⁷ Virtually every step of the livestock production process emits carbon or nitrogen into the atmosphere or hinders their sequestration in environmental reservoirs. Animals respire carbon dioxide directly, and ruminants can emit methane from their digestive tracts. Carbon dioxide also is emitted via the fossil fuels intensively used in feed grain and animal production. Most of the nitrogen concentrated in these animals via feed grains also is lost to the environment, via feces and urine. In addition to nitrous oxides, animal manure is a source for carbon dioxide and methane, as well as ammonia and sulfur dioxide, which also are agents of environmental acidification and air pollutants with respiratory health impacts.

Methane is the second most important greenhouse gas, because it is about 21 times more effective than carbon dioxide at trapping heat in the atmosphere; though produced in much smaller amounts, nitrous oxide traps heat 296 times more efficiently than carbon dioxide and persists in the atmosphere for more than a century.⁴⁷ Atmospheric levels of these gases, as well as regional concentrations, are determined by the numbers of animals being produced, how and where they are produced including their feed, and the manner in which manure is collected, treated, and distributed.

Industrialized food production greatly impacts climate, therefore, and a changing climate will more greatly impact food production. Climate change will change weather patterns and increase extreme weather, and the resultant increases in heat, drought, and downpours will have significant regional impacts on farming.⁴⁸ Because it diminishes soil fertility, depletes aquifers, and erodes the natural protections offered by multicropping and intact agroecosystems against disease and pests, industrialized agriculture leaves the food production system less resilient and more vulnerable to these climate-related stressors. Even apart from these implications for food production, “climate change endangers health in fundamental ways.”⁴⁹

Antibiotics

Industrialized animal production is intensive in its use of antibiotics, in addition to other resources. As much as 70% of all antimicrobials in the United States are given to otherwise healthy beef cattle, swine, and poultry in their feed as a routine part of their production⁵⁰; half of these antibiotics are thought

to be from 7 drug classes important to human medicine, including penicillins, tetracyclines, erythromycins, etc.⁵¹ US livestock producers routinely give antibiotics in feed to animals without diagnosed disease⁵² to promote production (growth), to boost feed efficiency, and to prevent or control the threat of disease among animals being raised industrially; that is, under confinement and stressed, and on an all-grain diet, which leaves them more prone to infection in the first place. Many industrialized countries no longer allow this practice. In countries or situations where these industrial conditions have been modified, large reductions in antibiotic use appear possible.⁵³

This is important because of the fundamental ecological nature of resistance. Bacteria freely travel within a bacterial ecosystem that includes hospitals and communities, as well as farms. Their routine exposure to antibiotics in the farm setting can select for strains of bacteria resistant to them and that are transmitted to the humans, often via contaminated food. Thus, the more antibiotics used in human settings, or in agriculture, the more it helps to create bacteria resistant to them and to undercut their effectiveness for everyone else. Resistance has progressed to where more bacterial infections in humans are approaching the point of being untreatable.

Effective antibiotics are a classic common good. The “tragedy of the commons” describes the tendency of unfettered individuals to overuse common goods for their own purposes, to the detriment of others who might benefit from them. There is now a great deal of scientific consensus that the routine use of antibiotics in industrialized animal production largely for economic purposes is a significant contributor to the epidemic of antibiotic resistance affecting humans.⁵²⁻⁵⁶

THE ROLE OF FARM AND FOOD POLICY

As technological innovations made industrialization of agriculture possible, and then as productionist thinking took root, public agricultural policies have further supported and encouraged these trends. Agricultural policy is a necessary window for understanding why we have the food system we have today, and yet published research on the policy context of recent decades is limited. The following summary draws from an article in *JHEN*,⁵⁷ Tufts University’s working paper, *Feeding the Factory Farm*,⁵⁸ as well as the University of Tennessee’s comprehensive 2003 report, *Rethinking US Agricultural Policy*.⁵⁹ A book-length treatment of the topic also has recently been published.⁶⁰

Virtually from its nationhood, US policy has promoted growth in its farmers’ abilities to produce more, first by settling homesteaders on frontier lands, later through government investments in research stations and extensions services to support and disseminate new agriculture technologies.⁵⁹ The focus of these policies, in general, has been production of certain food

commodities—corn, wheat, rice, milk, and later soybeans—that best lent themselves to large-scale production and that farmers in the middle of the country could easily grow, store, and ship long distances to the country's major population centers.⁵⁷

As crop farms industrialized and became more specialized in monocropping, the entire support infrastructure for agriculture at the regional level (research, extension, suppliers, storage, transport, distribution, etc) has followed suit, by focusing services on the continued industrial production, processing, and use of the same few crops.⁸ A 2002 National Research Council report signals concern that publicly funded agricultural research is biased toward further industrialization.⁶¹ Most public research dollars, for example, continue to be directed toward grain and oilseed production and meat and dairy production, at the expense of investments in vegetable, fruit, or nut production; pasture or perennial crops; or improving the ecosystem impacts of agriculture.

With an ever larger and increasingly urban population, historically there have been good reasons for the United States to expand food production capacity. In addition, there have been times of significant hunger in modern America. This, as well as periodic droughts, maldistribution problems, and war-related famine worldwide, particularly since World War II, lent popular support to the notion that American agriculture should be production driven. The belief then, as it continues to be for many, was that if policies supported rising production, both calories and nutritional benefits would eventually “trickle down” to consumers, making them healthier. This trickle-down approach to health and agriculture rested on the further proposition that if America's vast capacity to produce commodity crops were unleashed, it would address not only America's nutritional needs but those in the rest of the world.⁹

The very success of production-driven agriculture sowed the seeds of a different sort of problem: chronic overproduction. American agriculture in the 19th and early 20th centuries is replete with examples where supply outstripped demand, prices collapsed, and farmers suffered. During the Great Depression, bumper crops were left in the fields due to the lack of urban demand. Reflecting on this experience, Roosevelt's Secretary of Agriculture, Henry Wallace, thought the federal government needed to act to correct what he saw as a chronic overproduction problem inherent to commodity crop agriculture.

In most industries, markets work to correct oversupply. When there are too many widgets, inventories rise, prices fall, and producers quickly adjust to make fewer widgets. If widget prices stay chronically low, some producers go out of business, which reduces supply and increases prices. Like many economists from the 1920s to today,⁵⁸ Wallace based his thinking on evidence showing that for a variety of reasons, markets for corn and cotton crops (soy was not produced then) do not self-correct like those for widgets.⁶² For one

thing, individual small farmers cannot affect national prices with their decisions on how much to plant, cannot predetermine the weather or disease, and can only make planting decisions once a year; the net result is that farmers will tend to plant as much as they can, regardless of whether market prices for their commodities are high or low. When prices drop so low for so long that some farmers are unable to remain in business, they generally sell to larger entities, which keep producing, leading to increasing concentration and continued overproduction.¹⁴ Increasingly, today, larger producers are part of more vertically integrated companies able to offset low crop prices by profiting from other food products incorporating inexpensive commodities as ingredients.

To secure a food supply for the next generation, it is desirable for a nation to increase production capacity over time. Darryl Ray notes, however, that having the capacity to produce is not a mandate to exercise that capacity.⁵⁹ Ray and others maintain that when left to “the market,” commodity agriculture will tend to produce to capacity, with nothing in reserve, driving down prices to the detriment of individual farmers.

Observing the market failure inherent to commodity production, Wallace launched several New Deal programs. Their intent was for the federal government “to do for agriculture what it could not do for itself: manage productive capacity to provide sustainable and stable prices and income” (p. 15) for farmers.⁵⁹ Government used several mechanisms to manage year-to-year supplies, including asking farmers to idle some productive lands; establishing programs that set a price support or “floor price” that effectively guaranteed a minimum return on farmers’ crops and labor; and the creation of grain reserve programs, which, by taking excess grain supplies off the market until prices recover, serves to keep prices stable over time. Combined, these programs provided the framework for some of the most prosperous decades for US farmers.⁶³ Consumers and food processors also benefitted from predictable, stable prices. The net cost of these programs to the Treasury were relatively small, because some of the reserve programs actually earned revenue by buying low-priced grains and selling them when prices went higher.⁶⁴

Starting in 1965, however, and accelerating after the 1971 appointment of Earl Butz as US Secretary of Agriculture, the price support, grain reserves, and other federal programs to manage the supply of commodity crops started being dismantled. In 1974, Butz announced a new “cheap food” policy, where farmers were encouraged to plant “from fencerow to fencerow.” The case made by Butz was that by doing everything possible to spur commodity grain production, US farmers would capture insatiable and growing global markets with their cheap, unprocessed commodity grains.⁵⁹ Coming on the heels of crop failures overseas, and a temporary spike in global demand and prices for some commodities, many American farmers were persuaded of this notion—despite the lack of supporting evidence and

much evidence to the contrary. Convinced that their futures were in commodity crops, farmers shut down their livestock operations and literally tore down the fences and feed troughs.¹¹ These visual icons, and the linked production of both crops and food animals on a diversified farm that they represented, were gone.

With passage of the 1996 Farm Bill, the last of the supply management and price support tools of the previous 60 years were abandoned. Those advocating for the shift said that stable prices and a managed supply distorted the market and stopped farmers from responding to price signals.⁶⁵ The irony is that these programs had been initiated based on evidence (now largely forgotten) that farmers had been harmed by the inherent failure of commodity markets and the inability of farmers of those crops to respond appropriately to price signals. Those programs had worked effectively for decades by making sure that markets would operate to offer farmers a fair and stable price.

WHO BENEFITS FROM INDUSTRIAL POLICIES?

By its own measure, production-led agriculture over the last 60 years has been enormously successful. US farmers pushed corn productivity from just 30 bushels per acre in 1920, for example, to nearly 154 bushels in 2008, a jump of 600%.¹⁹ Based on a USDA survey, farmers in 2009 planted the second highest amount of corn in 62 years—more than 87 million acres' worth.⁶⁶ Through around 1970, these gains in production were accompanied by federal policies that succeeded in stabilizing prices and ensuring farm income. But when success is articulated not in terms of production or yield but rather in terms of the health of consumers, of farmers, and of the agroecosystem, then the success of production-led agriculture and the policies supporting it is less clear.

Consumers

The promised benefits from production agriculture to consumers have failed to trickle down in terms of better nutrition. US food production now offers a surfeit of inexpensive calories but not necessarily from foods that Americans need more of to meet healthy eating guidelines. The 2005 Dietary Guidelines for Americans, for example, indicate which foods ought to be eaten in relatively greater quantity: fruits and vegetables, whole grains, low-fat dairy, and lean meats. Yet less than one in 10 Americans meet the guidance for fruit and vegetable intake.⁶⁷ Someone eating a 2000-calorie-per-day diet ought to consume 9 half-cup servings (2 cups of fruit, 2½ cups of vegetables) daily, and the typical American eats just 3 servings.⁶⁸ Only 1 in 4 Americans eats 5 or more servings per day.⁶⁹ Average consumption is just 18% of the

recommended legumes, 35% of the orange vegetables, 36% of the green vegetables, and 43% of the fruit.⁷⁰

What foods *do* Americans consume in abundance? Highly processed “convenience” foods and sodas are the source for many extra fats, sugars, refined grains, and calories in the diet; animal products, meanwhile, are the only source of cholesterol and the primary source of saturated fats.⁷¹ Restaurant-based fast foods, on which Americans spend in excess of \$100 billion each year, comprise a large percentage of the calories and meat within the US diet.⁷² Thus, Americans overconsume diets high in calories, fats, sweeteners, and carbohydrates,⁷³ which in turn contributes to America’s high and very expensive rates of cancer, cardiovascular, diabetes, and other diet-related chronic diseases.

The average American’s daily energy intake rose by 300 kcal over just 15 years, from 1985 to 2000—the rise is thought to be an important driver of the obesity epidemic. Of those additional daily 300 calories, greater consumption of refined grains accounts for 46%, added fats for 24%, and added sugars for another 23%.⁷⁴

To a great degree, the sources of these calories are the few commodity crops for which America’s cheap food policy has promoted overproduction and low prices: wheat, soybeans, and especially corn. From essentially zero consumption in 1970, high fructose corn syrup (HFCS) came to account for the entire additional sweetener consumption since 1985, and then some⁷⁵; Americans today eat or drink about 12 teaspoons per day of HFCS, or approximately 1 in 10 daily calories.⁷⁵ Of added fats in the American diet, which have risen 24% since 1985, around 80% are derived from soybeans. “You have a whole régime here that’s worked to increase agricultural efficiency,” (p. A821) according to Tufts University’s James Tillotson. In effect, that régime encourages obesity at the expense of sound nutrition.^{76,77}

Numerous studies confirm that these overconsumed, energy (calorie)-dense, and nutrient-poor foods are also among the most accessible, most “affordable” foods in America, as measured by calories per retail dollar cost.^{78–80} Both USDA data (in Figure 3) and community retail food surveys⁸¹ demonstrate they also are the most inflation-resistant foods, meaning that they only get cheaper over time relative to healthier foods like fresh produce.

Eating more fruits and vegetables to reduce the energy density of the diet can aid in managing body weight^{82,83} as well as help prevent and reduce the risks of cancer, cardiovascular, and other expensive-to-treat chronic diseases.^{84,85} According to the USDA, healthier diets could prevent over \$71 billion each year in treatment costs, as well as in lost productivity and other indirect costs, for these diseases.⁸⁶ Yet healthy foods are becoming more expensive for the increasingly obese American population to eat, relative to other food categories.

Most public health or nutrition analyses focus on this shortfall in consumption, but production shortfalls are also important. The USDA has reported that for the entire nation to meet Dietary Guidelines’ recommendations with domestically produced fruits and vegetables, acreage devoted to growing

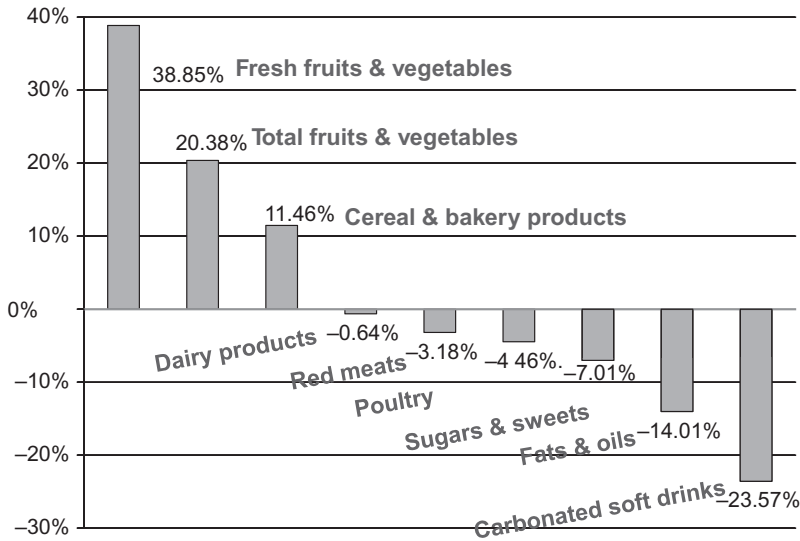


FIGURE 3 Retail food-price increases, 1985 to 2000.

Sources: Muller M, Schoonover H. *Food Without Thought: How U.S. Farm Policy Contributes to Obesity*. Minneapolis, MN: Institute for Agriculture and Trade Policy. 2004. Adapted using a CPI increase of 57% over that time period, from Putnam J, Allshouse J, Kantor LS. U.S. per capita food supply trends: More calories, refined carbohydrates and fats. *FoodReview* 2002; 25(3): 2-15.

produce would need to increase by approximately 13 million acres.^{87,88} At the same time, development is rapidly taking prime farmland out of production nationwide. The problem is most acute for the availability of produce, because 86% of domestic fruits and vegetables come from land under threat. The United States is becoming increasingly dependent on distant suppliers for fresh produce; in 2003, more than twice as many fresh vegetables were imported as were exported.⁷⁰

Farmers

Especially since the early 1970s, American farmers also have not fared particularly well under a production-led food system. After the full removal of supply management and price supports that occurred in the 1996 Farm Bill, supported crops (corn, soy, etc.) came to be significantly overproduced, with market prices falling in real terms.⁶⁵ Because fossil fuels, other inputs, and production generally cost more, the lower market prices often have failed to cover farmers' average costs to produce these crops. In Figure 4, Wise examines USDA data on US gross and net farm income to demonstrate that with the exception of the last few years, net farm income has mostly been declining.¹⁴

Even with the policy, begun in earnest after the 1996 Farm Bill, of direct USDA payments to farmers to grow crops in which America is already

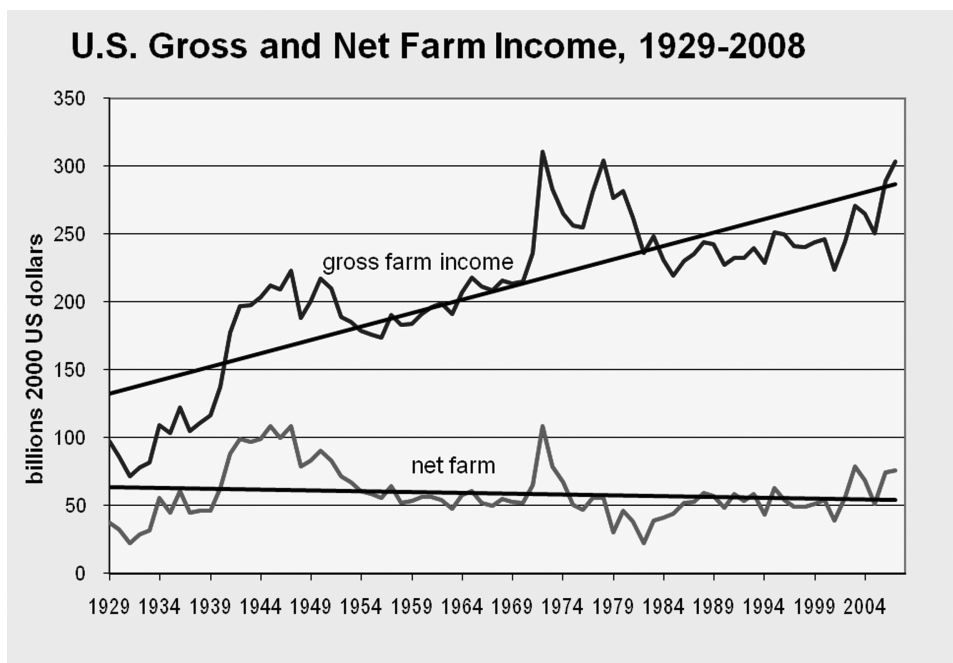


FIGURE 4 US gross and net farm income, 1929–2008 (\$2000 dollars).

Source: Used by author's permission. From Wise T. Global Development and Environment Institute Working Paper No.05-07: Identifying the Real Winners From U.S. Agricultural Policies. Global Development and Environmental Institute, Tufts University. 2006. Author updated to 2008, using data from USDA/ERS, Farm Income and Balance Sheet Indicators, 1929–2008.

oversupplied, farmers still sometimes lose money. A 2003 analysis by Darryl Ray and colleagues found that even when direct USDA payments are added to the income farmers have derived from selling their crops at low prices in the marketplace, the farmers' total returns for producing corn still were 6% below the cost of production in 2000 and just 1% above the cost of production in 2001. Soybean returns were worse, 9% and 11% below the cost of production in 2000 and 2001, respectively.⁵⁹

America's farmers have not "owned" global export markets for these crops, as was promised with the advent of cheap food policies, nor has demand in export markets functioned to increase chronically low market prices. Instead, predictably, Brazil and Asian countries vastly increased their own production of soy and other grains, serving to keep global prices low. At the same time, the increased volatility in market prices has heightened the risks to farmers. As food supply chains have vertically integrated, and globalized, farmers are receiving less and less of every food dollar spent—just 19 cents worth, today—with food processors, handlers, and marketers getting the balance.⁸⁹

The Agro-Ecosystem

How does the health of the agro-ecosystem fare from current policies? Many of the costs of American food production are “externalities”; that is, they are external to the industrial economic models that have guided the evolution of both crop monocultures and confined food animal production. As such, these costs rarely get quantified or reflected in public policy decisions. They are real costs nonetheless, with certain impacts on human and ecosystem health.

Michael Duffy and coauthors have estimated some of these externalities, including impacts on natural resources, wildlife, and diversity, and select impacts on humans from pesticides and pathogens as costing society between \$9.4 and \$20.6 billion per year.⁴⁶ This is a conservative estimate. It fails to include, for example, the human costs of the antibiotic resistance to which agricultural antibiotics contribute or any direct or indirect costs of diet-related chronic disease. When the market or policy-makers overlook these sorts of costs, the ultimate losers are future generations of consumers, farmers, and other Americans. They are the ones who likely will feel most acutely the loss of common goods, who will suffer longer-term health and welfare impacts of having less fertile soils, less abundant drinking water of lesser quality, or less effective antibiotics to nurse them to health when they are sick.

The greatest beneficiaries of farm policies that have kept commodity crop prices mostly low and below what it costs to produce them, on the other hand, are the largest companies buying these crops. These include global grain trading companies, which can buy inexpensive US commodity crops and then sell them abroad. Beneficiaries also include industrial livestock and poultry firms, for whom US corn and soybeans are the major feed ingredients. Feed grains account for around 60% of US poultry production costs and 47% to 65% of hog production costs; their market price is perhaps the largest determinant of how much profit an industrialized chicken or hog producer earns.¹⁴

Global meat producers buy feed on a least-cost basis in international markets and can sometimes shift production to wherever labor and the costs of pollution are lowest. As a share of total meat production, the international meat trade has doubled over the last decade.²⁵ Burke and Galloway demonstrate that though these global companies may appear to be offering “efficiencies” of production, they may be benefitting more from the extreme delinking of meat production and consumption.^{13,25}

Finally, beneficiaries include meat consumers in other countries. In eating meat produced in the United States, they virtually export back to the United States all the externalities of meat production incurred in the United States, including those from the intensive fertilizer and pesticides used to grow feed grains and the serious impacts on air and water quality that occur when animals are concentrated geographically. Due to its large-scale export

of feed grains, pork, and poultry meat, US resource use and pollution related to this trade is great. From 2000 to 2002, the United States marketed 62% of global corn exports, largely for overseas livestock and meat production.⁹⁰ Models assembled by Burke et al estimate that each year “922,000 tons of nitrogen are left behind in the U.S. due to the production of pig and chicken meat and feed that are exported abroad,” (p. 179)²⁵ an amount almost equivalent to the 1.2 million tons of nitrogen generated by production for meat consumption by Americans.²⁵ Alternatively, Galloway calculates that half of the nitrogen load represented by Japan’s consumption of pork and chicken meat is exported to the United States, where the feed grains are grown.¹³

Supporters of trends in industrialized food animal production, and the trade in meat and feed grains, have long argued they are the inevitable result of an efficient market rewarding economies of scale. Starmer and Wise find otherwise, however.⁶⁵ They conclude that federal commodity policies, put in place between 1974 and 1996, along with poor regulation of CAFO pollution, have handed global-scale industrialized meat producing companies an unfair discount on operating costs when compared to the competition.

Specifically, the Tufts researchers estimated that large hog producing companies, by virtue of buying feed grains an average of 26% below the actual cost of production from 1997 to 2005, enjoyed an economic benefit—an indirect public subsidy, really—worth \$8.5 billion. Chicken producers, similarly, saved \$11.25 billion in buying feed grains 21% below cost. In both cases, at least half of the total subsidy accrued to the largest 4 companies.⁶⁵

When combined with the advantage conferred by lax environmental regulation of their manure emissions, the benefit to a large-scale hog producer compared to a mid-scale, diversified hog producer, growing its own feed grains and recycling manure responsibly on site, is even greater. In an economic climate where the full life cycle costs of producing animal feed were reflected in the market prices, and where manure emissions were more stringently regulated, large-scale hog CAFOs would see their operating costs rise by between 17.4% and 25.7%.⁶⁵ CAFOs’ apparent economies of scale over smaller, more diversified farms, in other words, may be less the result of inherent efficiencies than they are the result of government policies that have favored large-scale industrialized feed grain and animal production.

CONCLUSION

How healthy is our food system? Of late, public discussion of food and health has mostly revolved around the epidemic of obesity and diet-related disease and chiefly from the consumer or retail food perspective. It is perhaps human nature to want to focus on a single human outcome, like obesity, and to try and find that single missing factor in the food system that can account for it. One can certainly find evidence that the existing food system

delivers too much cheap food too easily to consumers, and fresh produce is too scarce and too expensive, for example.

As with all systems, however, it is not one factor that makes for optimal function or dysfunction of the whole. A much broader and deeper understanding of health derives from looking at the food system as an entire system, from consumers back to food processors and farmers, and not only at the food itself but at the health implications of how that food is produced, processed, marketed, and distributed. In addition, the food system is a nature-based system: food and agriculture are inexorably rooted in the natural cycles of soil, air, carbon, nitrogen, and water on which growing things depend.

There are additional reasons for adopting a systems perspective towards food. In *Food Policy: Integrating health, environment and society*,¹⁶ Lang et al. argue the global food system is at a critical juncture, where better integration of health into food and farm policies is not only desirable but inevitable. Obesity is only one among many crises impacting both the food and health systems. Others include global population growth, climate change, accelerating global meat consumption and demand, the loss of arable land, declining water supplies, nitrogen imbalances, soil loss, and problems of food safety. Because the food system is a system, these crises are interrelated in their impacts. Together, they point to the unsustainability of the current course. Lang's thesis is that society cannot recognize these interconnected problems, or help bring about a food system capable of responding to them, if we continue in our collective failure to integrate health issues holistically into decision-making around food policy.

Looking specifically at the American food system and experience, this essay comes to the same conclusion: Industrialization and production-led thinking, especially that supported and encouraged by US cheap food policies since the mid-1970s, have helped shape a food system that now fails to provide very well for either consumers or farmers. Michael Hamm⁷⁰ points out that both the Dietary Guidelines and Healthy People 2010,⁹¹ like public health or nutrition analyses generally, fail to connect food-related problems at the consumer level (underconsumption of healthy foods) to factors elsewhere in the food system that exacerbate them (underproduction or trade policies). Not only the nutritional health of the US food supply is in doubt, however. Food system impacts on our soils, waters, and our supplies of effective antibiotics are increasingly costly, in social, economic, and environmental public health terms.

The American Medical Association has recently noted the disconnect between food policy, health, and sustainability in its 2009 Sustainable Foods report⁹²:

More attention also needs to be paid to the economic and regulatory policies that encourage the production of unhealthy, nonsustainable food at low immediate financial cost to consumers, at the expense of poorer health

outcomes that cost far more to treat with medications and procedures than investments (at societal and personal levels) in healthy food. (p. 7).

The dietetics⁹³ and public health⁹⁴ professions also have recently recognized the importance of healing this disconnect.

The better integration of health and sustainability concerns into food and agriculture policy decisions, as Lang suggests, would not only improve our understanding of the problems of the food system. It also could help bring about a food system that is healthier for consumers, for farmers, and for the agro-ecosystem. No elaborate model for a healthy food system exists, however. Preceding such a model there must first be a more general vision for what a healthy food system should look like. Other articles in this issue describe a more comprehensive strategy for attaining that vision. In light of the evidence presented here, however, it seems clear that sustainability is a prerequisite.

Sustainable food systems will be healthier for a host of reasons: because they reward diversity in food production in ways that will reduce monocultures, and the intensity of resource use and waste that go with them, while enhancing the diversity of foods locally available to American consumers; because carbon, nitrogen, and other potential nutrients can be economically cycled within a sustainable system, rather than becoming pollutants or wastes; and because sustainability requires looking at costs across the entire food system or life cycle in ways that would internalize all the social, environmental, and human costs that have too often been externalized and therefore ignored within the existing industrialized agriculture model.

More concretely, what might be done in the short term to move food and agriculture production policies in the direction of greater sustainability and health? Policy-makers should first consider corrections to the market failures and distortions created by existing policies. The following approaches would be a good start:

- Restore federal “supply management” policies that could again be effective in creating supplies of and prices for commodity crops in the marketplace that will address the tendency toward overproduction while also ensuring farmers can meet their full costs of production. This would also help address some of the market distortions that place healthy foods at a price disadvantage relative to foods based on cheap commodities.
- Consider price supports to farmers to encourage domestic production of the healthy foods that Americans ought to eat, as well as education and research infrastructure to support those farmers.
- Consider policies to lower anticompetitive barriers to entry of new farmers, thereby helping ensure that the nation will have future farmers with the available land, capital, and know-how to grow these crops sustainably.
- Consider federal research policies that would move prioritization away from industrialized production of animal feed crops toward the sustainable

domestic production of foods in which American diets are most deficient, according to federal healthy eating guidelines.

- Consider policy directives instructing federal research scientists to incorporate full life cycle costs of agricultural waste and pollution into analyses of the US food and agricultural system.
- Consider policies at the state or federal level to tax pesticides and other intensively used off-farm inputs (as other commercial products are taxed) to better reflect the full life cycle costs of their use and as a means of promoting agricultural methods more efficient in the use of these resources.
- Consider policies that could make the agricultural uses of fossil fuels, in particular, better reflect the full cost to the environment and human health of those uses.
- Regulate and/or price agricultural antibiotics to reflect their contribution to the overall problem of antibiotic resistance and to reflect the importance to the common good of having antibiotics that are effective for treating ill animals and people.

Of course, putting US food production on a more sustainable footing cannot solve all the problems confronting the food system today. Even if agricultural sustainability improves production in many settings as research now demonstrates, for example, these productivity gains may be insufficient in the long term to offset the higher demands being placed on agriculture by the combination of population growth and the growth in meat consumption globally. On the other hand, more sustainable agriculture can leave agroecosystems more resilient in the face of other challenges such as climate change, drought, and water scarcity.

REFERENCES

1. Finkelstein EA, Trogon JG, Cohen JW, Diet W. Annual medical spending attributable to obesity: payer- and service-specific estimates. Available at: <http://content.healthaffairs.org/cgi/content/abstract/hlthaff.28.5.w822v2>. Accessed August 17, 2009.
2. Costs of diseases associated with diet and inactivity. Center for Science in the Public Interest Web site. Available at: http://www.cspinet.org/nutritionapolicy/nutrition_policy.htm#4. Accessed July 20, 2009.
3. Food CPI and expenditures: food expenditures tables (Table 7). Economic Research Service, US Dept of Agriculture Web site. Available at: <http://www.ers.usda.gov/Briefing/CPIFoodAndExpenditures/data/>. Accessed July 11, 2009.
4. Health care spending in the United States and the OECD countries. Kaiser Family Foundation Web site. Available at: <http://www.kff.org>. Accessed July 16, 2009.
5. Income, poverty and health insurance (Figure 1). US Census Bureau Web site. Available at: <http://www.census.gov/prod/2008pubs/p60-235.pdf>. Accessed July 16, 2009.

6. Naylor RL. Managing food production systems for resilience. In: Chapin FS, Kofinas GP, Folke C, eds. *Principles of Natural Resource Stewardship: Resilience-Based Management in a Changing World*. New York, NY: Springer; 2008:259–280.
7. Jackson LL. Who “designs” the agricultural landscape? *Landscape*. 2008;27:1–8.
8. Altieri MA, Nicholls CI. *Agroecology and the Search for a Truly Sustainable Agriculture*. 1st ed. Available at: <http://www.agroeco.org/doc/agroecology-engl-PNUMA.pdf>. Accessed July 17, 2009.
9. Lang T, Heasman M. *Food Wars: The Global Battle for Mouths, Minds and Markets*. London: Earthscan, 2004.
10. Kirschenmann F, Stevenson S, Buttel F, Lyson T, Duffy M. Why worry about the agriculture of the middle? Available at: <http://www.agofthemiddle.org>. Accessed July 16, 2009.
11. Ray DE. Agricultural policy for the twenty-first century and the legacy of the Wallaces (The Fourth Annual Pesek Colloquium Lecture). The Henry A. Wallace Endowed Chair for Sustainable Agriculture Web site. Available at: http://www.wallacechair.iastate.edu/PDF/Daryll_RAY.pdf. Accessed July 16, 2009.
12. Heller MC, Keoleian GA. Assessing the sustainability of the US food system: a life cycle perspective. *Agric Syst*. 2003;76:1007–1041.
13. Galloway JN, Burke M, Bradford GE, et al. International trade in meat: the tip of the pork chop. *Ambio*. 2007;36:622–629.
14. Wise T. Identifying the real winners from US agricultural policies. Global Development and Environmental Institute, Tufts University Web site. Available at: <http://www.ase.tufts.edu/gdae/Pubs/wp/05-07RealWinnersUSAg.pdf>. Accessed July 26, 2009.
15. Ribaudo M, Gollehon N, Aillery M, et al. Agricultural economic report 824: manure management for water quality: costs to animal feeding operations of applying manure nutrients to land. Available at: <http://www.ers.usda.gov/Publications/AER824>. Accessed July 23, 2009.
16. Lang T, Barling D, Caraher M. *Food Policy: Integrating Health, Environment and Society*. New York, NY: Oxford University Press; 2009.
17. Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. *Nature*. 2002;418:671–677.
18. Jackson W. The modern dilemma and the challenge to systems thinkers. *Syst Res*. 2002;19:399–405.
19. Horrigan L, Lawrence RS, Walker P. How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environ Health Perspect*. 2002;110:445–456.
20. US Environmental Protection Agency. National water quality inventory: report 2000. Available at: <http://www.epa.gov/305b/2000report/>. Accessed July 23, 2009.
21. Potera C. Corn ethanol goal revives dead zone concerns. *Environ Health Perspect*. 2008;116:A242–A243.
22. Nolan BT, Hiatt KJ, Ruddy BC. Probability of nitrate contamination of recently recharged groundwaters in the conterminous United States. *Environ Sci Technol*. 2002;36:2138–2145.
23. Pimental D, Berger B, Filiberto D, et al. Water resources: agricultural and environmental issues. *Bioscience*. 2004;54:909–918.

24. McGuire VL. Water level changes in the High Plains Aquifer (Fact Sheet). US Geological Survey Web site. Available at: <http://pubs.usgs.gov/fs/2001/fs-029-01/>. Accessed August 19, 2009.
25. Burke M, Oleson K, McCullough E, Gaskell JA. global model tracking water, nitrogen, and land inputs and virtual transfers from industrialized meat production and trade. *Environ Model Assess*. 2009;14(2):179–193.
26. Pimentel D, Harvey C, Resosudarmo P, et al. Environmental and economic costs of soil erosion and conservation benefits. *Science*. 1995;267:1117–1123.
27. Pimentel D, Greiner A, Bashore T. Economic and environmental costs of pesticides use. *Arch Environ Contam Toxicol*. 1991;21:84–90.
28. Benbrook CM. Impacts of genetically engineered crops on pesticide use in the United States: the first eight years. BioTech InfoNet Web site. Available at: <http://www.biotech-info.net.technicalpaper6.html>. Accessed September 1, 2009.
29. Centers for Disease Control and Prevention. *Third National Report on Human Exposure to Environmental Chemicals*. Available at: <http://www.cdc.gov/exposurereport/>. Accessed September 1, 2009.
30. Baker BP, Benbrook CM, Groth E, Benbrook KL. Pesticide residues in conventional, IPM-grown and organic foods: insights from three US data sets. *Food Addit Contam*. 2002;19(5):427–446.
31. Hayes TB, Case P, Chui S, et al. Pesticide mixtures, endocrine disruption, and amphibian declines: are we underestimating the impact? *Environ Health Perspect*. 2006;114(suppl 1):40–50.
32. Pesticide issues in the works: honey bee colony collapse disorder. Environmental Protection Agency Web site. Available at: <http://www.epa.gov/opp00001/about/intheworks/honeybee.htm>. Accessed July 23, 2009.
33. Watson WA, Litovitz TL, Rodgers GC Jr, et al. 2002 Annual report of the American Association of Poison Control Centers Toxic Exposure Surveillance System. *Am J Emerg Med*. 2003;21:353–421.
34. Ontario Family Physicians. Pesticides literature review. Available at: <http://www.ocfp.on.ca/english/ocfp/communications/currentissues/pesticides/>. Accessed July 23, 2009.
35. Andreotti G, Freeman LE, Hou L, et al. Agricultural pesticide use and pancreatic cancer risk in the Agricultural Health Study Cohort. *Int J Cancer*. 2009;124:2495–2500.
36. Koutros S, Lynch CF, Ma X, et al. Heterocyclic aromatic amine pesticide use and human cancer risk: results from the US Agricultural Health Study. *Int J Cancer*. 2009;124:1206–1212.
37. Lee WJ, Sandler DP, Blair A, Samanic C, Cross AJ, Alavanja MCR. Pesticide use and colorectal cancer risk in the Agricultural Health Study. *Int J Cancer*. 2007;121:339–346.
38. Montgomery MP, Kamel F, Saldana TM, Alavanja MC, Sandler DP. Incident diabetes and pesticide exposure among licensed pesticide applicators: Agricultural Health Study, 1993–2003. *Am J Epidemiol*. 2008;167:1235–1246.
39. Smil V. Nitrogen and food production: proteins for human diets. *Ambio*. 2002;31:126–131.

40. Fertilizer use and price, 1960-2007. Economic Research Service, US Dept of Agriculture Web site. Available at: <http://www.ers.usda.gov/Data/FertilizerUse/>. Accessed July 21, 2009.
41. Tilman D. The greening of the green revolution. *Nature*. 1998;396:211–212.
42. Khan SA, Mulvaney RL, Ellsworth TR, Boast CW. The myth of nitrogen fertilization for soil carbon sequestration. *J Environ Qual*. 2007;36:1821–1832.
43. Bhumbra DK. Agriculture practices and nitrate pollution of water. West Virginia University Extension Service Web site. Available at: <http://www.caf.wvu.edu/~forage/nitratepollution/nitrate.htm>. Accessed July 23, 2009.
44. Centers for Disease Control and Prevention. Concentrated animal feeding operations (CAFOs). Available at: <http://www.caf.wvu.edu/~forage/nitratepollution/nitrate.htm>. Accessed July 23, 2009.
45. Pimental D, Pimental MH. *Food, Energy and Society*. 3rd ed. Boca Raton, Fla: CRC Press; 2006.
46. Tegmeier E, Duffy M. External costs of agricultural production in the United States. *Int J Agric Sustain*. 2004;2:1–20.
47. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C. *Livestock's Long Shadow: Environmental Issues and Options*. Available at: <http://www.fao.org/docrep/010/a0701e/a0701e00.HTM>. Accessed September 1, 2009.
48. Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, Naylor RL. Prioritizing climate change adaptation needs for food security in 2030. *Science*. 2008;319:607–610.
49. The impact of climate change on human health. Statement by WHO Director-General Dr. Margaret Chan. World Health Organization Web site. Available at: <http://www.who.int/mediacentre/news/statements/2008/s05/en/index.html>. Accessed July 22, 2009.
50. Pew Commission on Industrial Farm Animal Production, a Project of the Pew Charitable Trusts and Johns Hopkins Bloomberg School of Public Health. Putting meat on the table: industrial farm animal production in America. Available at: http://www.jhsph.edu/clf/programs/farming/proj_pew1.html. Accessed July 22, 2009.
51. Mellon M, Benbrook C, Benbrook KL. Hogging it: estimates of antimicrobial abuse in livestock. Union of Concerned Scientists Web site. Available at: <http://www.ucsusa.org>. Accessed July 22, 2009.
52. US Food and Drug Administration. Statement of Joshua M. Sharfstein, MD, Principal Deputy Commissioner of Food and Drugs, before the House Committee on Rules, July 13, 2009. FDA Web site. Available at: <http://www.fda.gov/NewsEvents/Testimony/ucm171715.htm>. Accessed September 1, 2009.
53. World Health Organization. *Impacts of antimicrobial growth promoter termination in Denmark: the WHO international review panel's evaluation of the termination of the use of antimicrobial growth promoters in Denmark*. Department of Communicable Diseases, Prevention and Eradication, Collaborating Centre for Antimicrobial Resistance in Foodborne Pathogens. Available at: <http://www.who.int/salmsurv/links/gssamrgrowthreportstory/en/>. Accessed January 5, 2009.
54. General Accounting Office. Federal agencies need to better focus efforts to address risk to humans from antibiotic use in animals. GAO-04-490. Available at: <http://www.gao.gov/new.items/d04490.pdf>. Accessed September 1, 2009.

55. Aarestrup FM, Wegener HC, Collignon P. Resistance in bacteria of the food chain: epidemiology and control strategies. *Expert Rev Anti Infect Ther.* 2008;6: 733–750.
56. Smolinski MS, Hamburg MA, Lederberg J. *Microbial Threats to Health: Emergence, Detection and Response.* Washington, DC: National Academies Press; 2003.
57. Wallinga D, Schoonover H, Muller M. Considering the contribution of US agricultural policy to the obesity epidemic: overview and opportunities. *J Hunger Environ Nutr.* 2009;4:3–19.
58. Starmer E, Witteman A, Wise T. Feeding the factory farm: implicit subsidies to the broiler chicken industry (GDAE Working Paper No. 06-03). Global Development and Environmental Institute, Tufts University Web site. Available at: <http://www.ase.tufts.edu/gdae/Pubs/wp/06-03BroilerGains.pdf>. Accessed July 16, 2009.
59. Ray D, De La Torre Ugarte D, Tiller K. Rethinking US agricultural policy: changing course to secure farmer livelihoods worldwide. University of Tennessee, Agricultural Policy Analysis Center. Available at: <http://www.apacweb.ag.utk.edu>. Accessed July 23, 2009.
60. Winders B. *The Politics of Food Supply: US Agricultural Policy in the World Economy.* New Haven, Conn: Yale University Press; 2009.
61. National Research Council. *Publicly Funded Agricultural Research and the Changing Structure of US Agriculture.* Washington, DC: National Academies Press; 2002. Available at: <http://www.nap.edu>. Accessed July 23, 2009.
62. Ray DE. Why grain markets don't self-correct under current policies. Testimony before the United States Senate Committee on Agriculture, Nutrition and Forestry. University of Tennessee, Agricultural Policy Analysis Center. Available at: <http://www.agpolicy.org/pubs/grainmkt0899.pdf>. Accessed July 23, 2009.
63. Wallinga D, Schoonover H, Muller M. Background paper prepared for the Wingspread Conference: considering the contribution of US agricultural policy to the obesity epidemic: overview and recommendations. Available at: http://www.healthyeatingresearch.org/images/stories/her_wingspread/7mullerbackgroundpaper.pdf. Accessed July 23, 2009.
64. Gardner B. Agriculture in the twentieth century. In: Whaples R, ed. *EH.Net Encyclopedia.* Available at: <http://eh.net/encyclopedia/article/gardner.agriculture.us>. Accessed July 23, 2009.
65. Starmer E, Wise TA. Living high on the hog: factory farms, federal policy, and the structural transformation of swine production. Available at: <http://www.ase.tufts.edu/gdae/>. Accessed July 23, 2009.
66. Wilson J, Bjerga A. US corn acreage climbs as dry weather spurs seeding. Available at: <http://www.Bloomberg.com>. Accessed June 30, 2009.
67. Kimmons J, Gillespie C, Seymour J, Serdula M, Blanck HM. Fruit and vegetable intake among adolescents and adults in the United States: percentage meeting individualized recommendations. *Medscape J Med.* 2009;11:26.
68. US Dept. of Health and Human Services and US Dept of Agriculture. *Dietary Guidelines for Americans, 2005.* 6th ed. Washington, DC: US Government Printing Office; 2005.
69. Blanck HM, Gillespie C, Kimmons JE, Seymour JD, Serdula MK. Trends in fruit and vegetable consumption among US men and women, 1994-2005. *Prev Chronic Dis.* 2008;5:A35.

70. Hamm M. Linking sustainable agriculture and public health: opportunities for realizing multiple goals. *J Hunger Environ Nutr*. 2008;3:169–185.
71. Walker P, Rhubart-Berg P, McKenzie S, Kelling K, Lawrence RS. Public health implications of meat production and consumption. *Public Health Nutr*. 2005;8:348–356.
72. Jahren AH, Kraft RA. Carbon and nitrogen stable isotopes in fast food: signatures of corn and confinement. *Proc Natl Acad Sci U S A*. 2008;105:17855–17860.
73. Wells HF, Buzby JC. Dietary assessment of major trends in US food consumption, 1970-2005. Washington, DC: Economic Research Service, US Dept of Agriculture; 2008. Economic Information Bulletin No. 33.
74. Putnam J, Allshouse J, Kantor LS. US per capita food supply trends: more calories, refined carbohydrates, and fats. *Food Rev*. 2002;25(3):2–15.
75. Economic Research Service briefing room. Sugars and sweeteners: data tables. Available at: <http://www.ers.usda.gov/Briefing/Sugar/>. Accessed July 12, 2009.
76. Tillotson JE. America's obesity: conflicting public policies, industrial economic development, and unintended human consequences. *Annu Rev Nutr*. 2004;24:617–643.
77. Fields S. The fat of the land: do agricultural subsidies foster poor health? *Environ Health Perspect*. 2004;112:A820–A823.
78. Drewnowski A, Darmon N, Briend A. Replacing fats and sweets with vegetables and fruits—a question of cost. *Am J Public Health*. 2004;94:1555–1559.
79. Darmon N, Briend A, Drewnowski A. Energy-dense diets are associated with lower diet costs: a community study of French adults. *Public Health Nutr*. 2004;7:21–27.
80. Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. *Am J Clin Nutr*. 2004;79:6–16.
81. Monsivais P, Drewnowski A. The rising cost of low-energy-density foods. *J Am Diet Assoc*. 2007;107:2071–2076.
82. Rolls BJ, Drewnowski A, Ledikwe JH. Changing the energy density of the diet as a strategy for weight management. *J Am Diet Assoc*. 2005;105(5, suppl 1):S98–S103.
83. Jansen MC, Bueno-de-Mesquita HB, Feskens EJ, Streppel MT, Kok FJ, Kromhout D. Quantity and variety of fruit and vegetable consumption and cancer risk. *Nutr Cancer*. 2004;48(2):142–148.
84. Retelny VS, Neuendorf A, Roth JL. Nutrition protocols for the prevention of cardiovascular disease. *Nutr Clin Pract*. 2008;23:468–476.
85. Demark-Wahnefried W, Rock CL, Patrick K, Byers T. Lifestyle interventions to reduce cancer risk and improve outcomes. *Am Fam Physician*. 2008;77:1573–1578.
86. Frazao E. High costs of poor eating patterns in the United States. In: Frazao E, ed. *America's Eating Habits: Changes and Consequences*. Washington, DC: Economic Research Service, US Dept of Agriculture; 1999:5–32. Agriculture Information Bulletin No. 750.
87. Buzby JC, Wells HF, Vocke G. Possible implications for US agriculture from adoption of select dietary guidelines. Available at: <http://www.ers.usda.gov/Publications/ERR31/>. Accessed September 1, 2009.
88. Huang S, Huang K. Increased U.S. imports of fresh fruit and vegetables. Available at: <http://www.ers.usda.gov/Publications/FTS/2007/08Aug/FTS32801/>. Accessed September 1, 2009.

89. US Dept of Agriculture. Food marketing system in the US: price spreads from farm to consumer. Available at: <http://www.ers.usda.gov/Briefing/FoodMarketingSystem/pricespreads.htm>. Accessed July 23, 2009.
90. Ray D. 88 Percent: three countries account for most corn trade. Available at: http://www.southwestfarmpress.com/mag/farming_percent_three_countries/. Accessed July 15, 2009.
91. US Dept of Health and Human Services. *Healthy People 2010: Understanding and Improving Health*. 2nd ed. Washington, DC: US Government Printing Office; 2000. Available at: <http://www.healthypeople.gov/Document/pdf/uih/2010uih.pdf>. Accessed January 15, 2008.
92. American Medical Association. Sustainable foods report (8-A-09). Available at: <http://www.ama-assn.org/ama1/pub/upload/mm/443/csaph-rep8-a09.pdf>. Accessed September 1, 2009.
93. Healthy land, healthy people: building a better understanding of sustainable food systems for food and nutrition professionals. Available at: http://www.eatright.org/ada/files/Sustainable_Food_Systems_Opportunities_for_Dietitians.pdf. Accessed September 1, 2009.
94. American Public Health Association. Toward a healthy, sustainable food system. Available at: <http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1361>. Accessed July 15, 2009.