Food, Land and Water: Can Wisconsin Find Its Way?

Our food system is under stress, and so are the natural resources that sustain it.
Where do we go from here?

By James Matson*

Feeding Wisconsin

Without food, there is no life. And without land and water, there is no food. Our daily food needs bind us to the earth just as surely as if we were trees. We forget that at our peril.

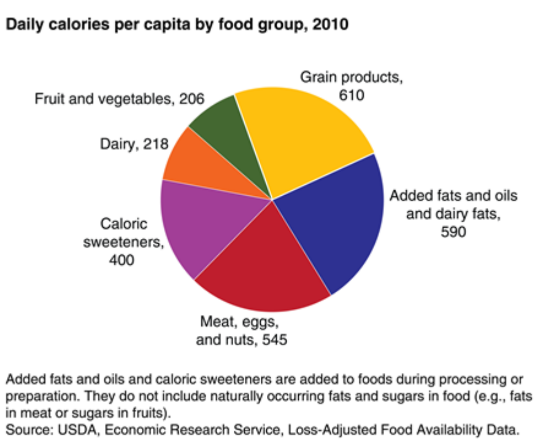
Photo courtesy of The Lake Today

Wisconsin now has nearly 6 million people, and there may be 7 million when today's children retire.[1] Most of us live in cities and suburbs, with no farms in sight. Together, we in Wisconsin consume (or waste) about 30 million pounds of food *every single day*.[2] Our cities have about a week's supply of food on hand at any given time.[3] Our food supply must be replenished without fail, every day of every year, for all generations to come.

Our food supply depends on land and water. Wisconsin consumes (or wastes) about 30 million lbs. of food every day, and our population is growing. Our cities have about one week's supply of food on hand at any given time.

Although food is a basic necessity, our diet is partly a matter of personal choice; and our choices strongly affect our environmental "footprint." In the year 2000, the average U.S. resident consumed (or wasted) about 593 pounds of milk and dairy products, 428 pounds of vegetables, 263 pounds of meat and poultry, 280 pounds of fruit, 200 pounds of grain products, 250 eggs, 152 pounds of added sweeteners, and 75 pounds of added fats and oils.[4]

Grain and animal products provide most of the energy (calories) in our diet. Food calories are essential for life, but most of us consume far more than we need. In the year 2000, the U.S. consumed nearly 25% more calories *per person* than we did in 1970.[5] Refined grain products, fats, oils, and added sweeteners accounted for nearly all of the increase.[6]

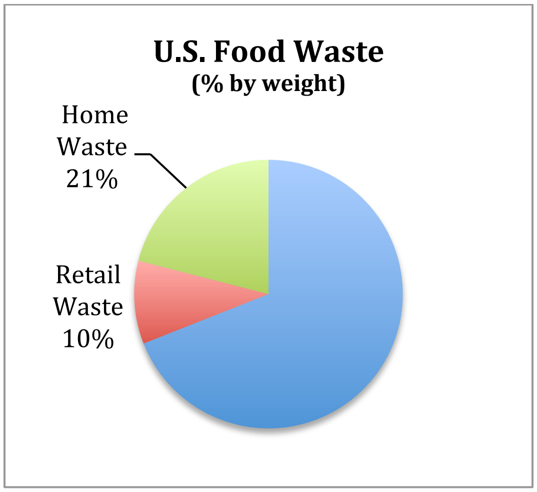


Our diet is partly a matter of choice, and our choices strongly affect our environmental "footprint." Grain and animal products provide most of the energy calories in our diet. In 2000, the U.S. consumed 25% more calories per person than we did in 1970.

Chart: USDA-ERS

* James Matson retired in 2011 after 28 years as chief legal counsel for the Wisconsin Department of Agriculture, Trade and Consumer Protection.

Much of the U.S. food supply is wasted. In 2010, we wasted about 31% of our food by weight, including 10% at retail and 21% in our homes.[7] That amounts to 1,249 Calories (kcal) per person per day. The top wasted food groups were meat, poultry and fish (30% of waste), vegetables (19% of waste) and dairy (17% of waste).[8] About 30 million *tons* of food are dumped in U.S. landfills each year – enough to feed everyone in Wisconsin for about 5 years.[9] Meanwhile, nearly 15% of U.S. households suffer from food insecurity.[10] When we waste food, we are also wasting land, water, energy and farm inputs. The U.S. government has called for voluntary efforts to reduce food waste by 50% in 15 years.[11]



The U.S. wastes almost 1/3 of its total food supply. We dump about 30 million tons of food in landfills each year – enough to feed everyone in Wisconsin for 5 years. When we waste food, we also waste land, water, energy and farm inputs.

Chart based on USDA-ERS data.

Food from Far Places

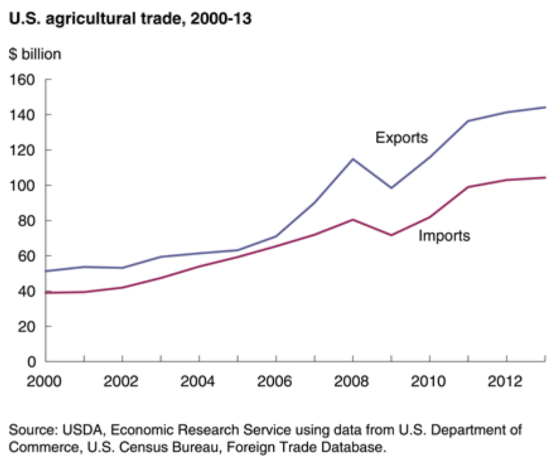
Although our food comes from the land, much of that land is located outside Wisconsin. Wisconsin is part of a vast worldwide food system, and is both an importer and exporter of food. As "America's Dairyland," we ship 90% of our dairy products (mainly cheese) to other states and foreign countries[12] – bringing dollars back home. But like the rest of the U.S., we get nearly half of our fresh vegetables from a single distant location – the now drought-stricken state of California.[13] Over the years, food production has become far more geographically specialized. Most of our food now travels many hundreds, if not thousands, of miles.

Much of our food now comes from foreign countries. U.S. food imports *doubled* in the last decade, to over $104 billion in 2013.[14] The U.S. now imports about 17% by volume of its total food supply,[15] including 50% of our fresh fruit (especially bananas and grapes), 20% of our fresh vegetables (mainly from Mexico), and up to 90% of our seafood (about half produced by aquaculture, and much illegally caught).[16] About two-thirds of our apple juice comes from China.[17] Nearly 116,000 foreign facilities ship food to the U.S. (over 13,000 in Japan and 10,000 in China alone).[18] U.S. authorities inspect less than 2% of all food import shipments.[19]

Feeding the World

The U.S. *exports* even more food than it imports. We are the world's biggest food exporter, and much of that food comes from the rich prairie soil of the Upper Midwest – one of the world's most important agricultural resources. We export about 20% by volume of all U.S. farm products[20] – including 50% of our wheat, 40% of our soybeans, 20% of our corn, 20% of our processed vegetables, 20% of our pork and poultry, and 16% of our milk products.[21] We produce far more of these food staples than we need for domestic consumption alone.

U.S. agricultural exports nearly *tripled* in the last decade, to over $175 billion in 2014.[22] Wisconsin participated in this export surge. In 2014, Wisconsin exported more than $3.6 billion worth of agricultural products to more than 145 countries.[23] Wisconsin food exports grew by nearly 14% in 2014, continuing an upward trend.[24] Wisconsin *dairy* exports to foreign countries grew by 41% in 2013 alone.[25]

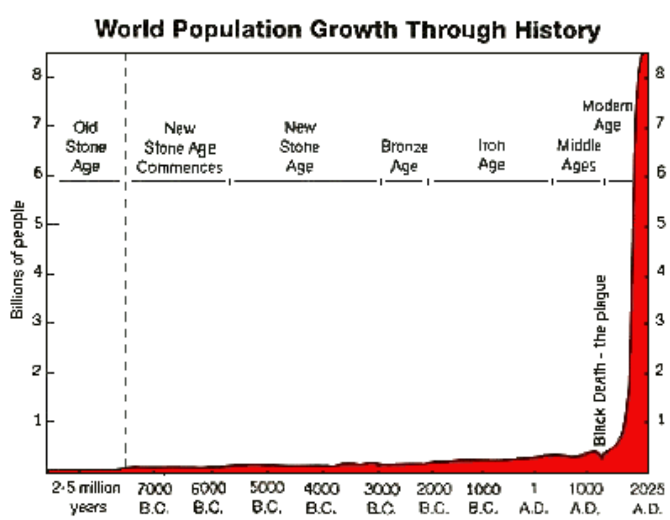


Most Wisconsin food products are shipped out of the state, and most of what we eat comes from beyond our state borders. Food production is geographically specialized, and food travels long distances. The U.S. imports and exports more food than ever before.

Chart: USDA-ERS

Our food system, like our financial system, is now heavily exposed to the world market. A change in Chinese consumption, a poor crop in Brazil, or a dairy surplus in New Zealand can have a big impact on commodity prices and land use decisions in Wisconsin. The world food market, like the world financial market, is highly volatile. For example, the world corn price dropped 50% from its 2012 record high after U.S. farmers increased corn output by 30%.[26] But despite short-term volatility, global food demand has been growing steadily over the long haul.

In the last 100 years (just one long human lifetime), the Wisconsin population has more than *doubled*, the U.S. population has more than *tripled*, and the world population has more than *quadrupled.*[27] World population, now at 7.3 billion, is projected to reach 9 or 10 billion by 2050.[28] Although population growth rates are now slowing in most countries, population totals are still climbing. Demographic momentum and greater longevity will continue to drive population growth through the mid-21st Century, unless there is an unforeseen catastrophe.



Population growth and dietary shifts are driving a surge in world food demand. Our food system, like our financial system, is now heavily exposed to the world market.

A long view of human population growth.

Chart: The Population Reference Bureau (1994).

Changing diets are also having a big impact on food demand. Rising nations like China want more animal protein in their diets, and they can now afford to pay for it on world markets. World meat production *quadrupled* over the last 50 years, and world milk production *doubled*.[29] China's *per capita* dairy consumption grew more than five-fold between 1991 and 2011 alone.[30] By one U.N. estimate, the world may consume 73% *more* meat and eggs and 58% *more* dairy products by 2050.[31]

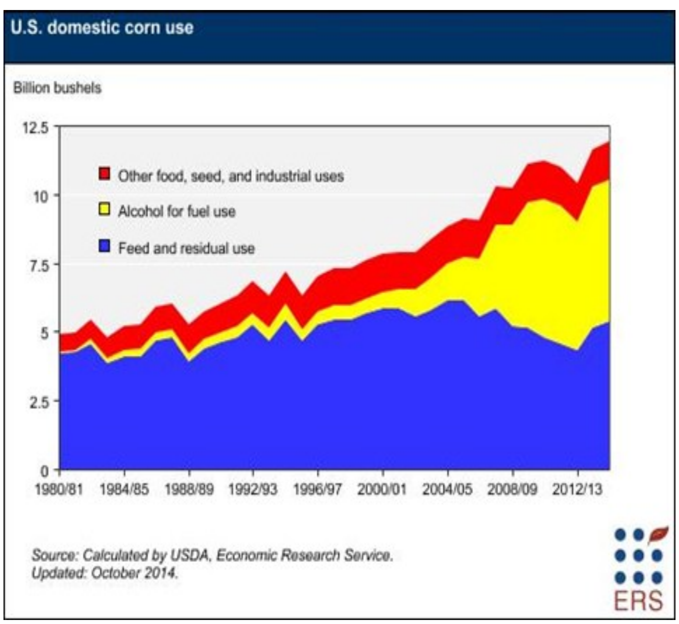
A diet high in animal protein (such as the U.S. diet) typically requires far more land, water and crop production than a diet based on plant protein alone, because livestock require a lot of feed.[32] In fact, the biggest cash crops in the U.S. – corn and soybeans – go mainly to feed livestock.[33] At least half of our total corn crop (including exported corn) goes for livestock feed, as does most of our soybean crop.[34]

Feeding Our Cars and Our Waistlines

U.S. *cars* also compete with livestock and people as corn consumers. Ethanol fuel production now claims 30-40% of the entire U.S. corn crop,[35] or 11-15% of the *world* corn crop (in 2014, the U.S. produced almost 37% of the world's corn).[36] Federal ethanol mandates have spurred a rise in U.S. corn acreage,[37] displacing other crops and land uses such as pasture and grassland.[38]

Only about 10% of the total U.S. corn crop goes directly to human food, and most of that goes for refined oils and sweeteners.[39] High fructose corn syrup, a leading ingredient in soda, fruit drinks and processed foods, now provides much of the added sugar in the U.S. diet. In 1945, Americans drank 4 times more milk than soft drinks; but by 1997, Americans drank 2.5 times more soft drinks than milk.[40] A sugar-heavy U.S. diet is fueling an obesity and diabetes epidemic.[41]

If current use (and waste) trends continue, the world will need to produce *twice as much* grain and forage by 2050 to meet rising food, feed and bio-fuel demands.[42] Without higher production or a change in crop uses, or both, world food and feed prices could go through the roof. That will affect food security and social stability – especially in volatile countries like Egypt, Pakistan and Nigeria that spend nearly half of their household income on food.[43]



If current use (and waste) trends continue, the world may need to produce twice as much grain by 2050 to keep food prices stable. But food production is already testing the limits of our land and water resources.

Today, most U.S. corn goes for livestock feed and car fuel. Only about 10% of the U.S. corn crop goes directly to human food (mostly refined oils and sweeteners).

Cars consume a growing share of our corn crop.

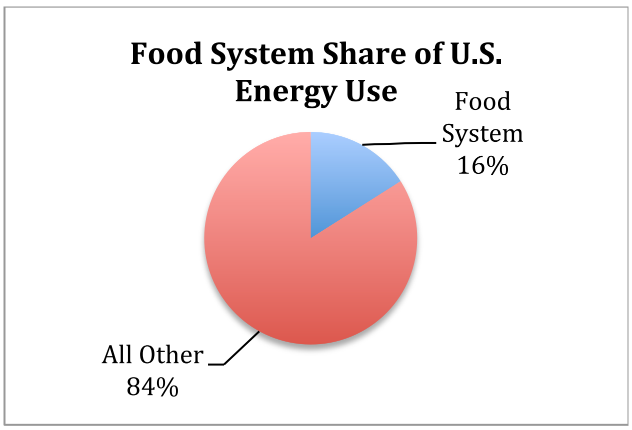
Chart: USDA-ERS. Chart does *not* include exported corn, which accounts for up to 20% of the U.S. corn crop and goes mainly for livestock feed in other countries.

Current agricultural production is already testing the limits of our land and water resources. Even with improved technology and management, further growth will come at increasing cost to the environment. While surging demand may be an economic boon to some, it will almost surely increase environmental stress in Wisconsin and throughout the world.

Food, Energy and Greenhouse Gas

In 1918, within memory of a few people alive today, horses and mules did much of our nation's work and consumed 25% of all U.S. crop production.[44] But the age of animal power has ended in the U.S. and much of the world. Since 1918, the U.S. has dramatically increased economic output by substituting fossil fuel and energy-driven technology for animal and human labor. The U.S., with 5% of the world's population, now consumes about 20% of the world's annual fossil fuel production (all uses).[45]

The U.S. food system, like the rest of the U.S. economy, uses a lot of energy. According to one careful USDA study, the food system (farm through home kitchen) now accounts for about 16% of all U.S. energy use.[46] The vast majority of that energy comes, ultimately, from fossil fuel.[47] It now takes about 7-10 Calories (kcal) of fossil fuel to produce, process and deliver just *one* Calorie (kcal) of food energy to our bodies.[48] We live, almost literally, on fossil fuel.



From farm through home kitchen, the U.S. food system accounts for about 16% of all U.S. energy use.

We use about 7-10 Calories of fossil fuel to produce, process and deliver each food Calorie that we consume. We live, almost literally, on fossil fuel.

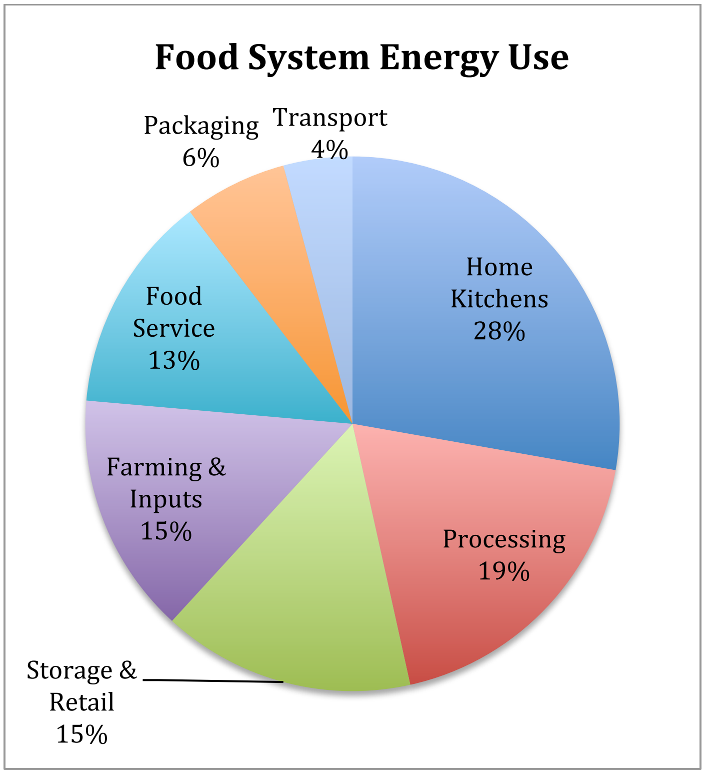
Chart based on Canning, et al., "Energy Use in the U.S. Food System," USDA-ERS, ERR-94 (March 2010)

Household energy uses related to food (home refrigerators, freezers, stoves, dishwashers, microwaves, garbage disposals, food processors, toasters, grocery store trips and the like) are, by far, the biggest energy users in the U.S. food system.[49] Household uses account for about 28% of all food system energy use, followed by commercial food processing at 19%.[50]

Farming, including energy embodied in farm inputs like fertilizer and pesticides, accounts for just 15% of all food system energy use. Non-household transportation accounts for just 4%.[51] Relatively low-cost, fuel-efficient bulk transportation has contributed to the "de-localization" and even globalization of our food system. In many cases, it costs less to transport food from specialized production sites in California, Mexico or even China than to produce it locally.

When we burn fossil fuel, we produce carbon dioxide, one of several "greenhouse gases" that contribute to global warming.[52] The U.S. is one of the world's top greenhouse gas emitters,[53] and a significant share of that greenhouse gas comes from our food system. Assuming that the U.S. food system (farm through home kitchen) accounts for 16% of U.S. fossil fuel use, it also accounts for roughly 16% of U.S. *carbon dioxide* emissions.[54] Those carbon dioxide emissions represent about 13% of all U.S. greenhouse gas emissions.[55]

Farms also emit nitrous oxide (mainly from nitrogen fertilizer and livestock manure) and methane (mainly from cattle digestive processes and livestock manure), which together represent 9% of all U.S. greenhouse gas emissions.[56] All told, the U.S. food system (farm through home kitchen) accounts for roughly 22% of U.S. greenhouse gas emissions.



Home kitchens are the biggest energy users in the U.S. food system.

The U.S. food system, from farm through home kitchen, accounts for roughly 22% of all U.S. greenhouse gas emissions.

Chart based on Canning, et al., "Energy Use in the U.S. Food System," USDA-ERS, ERR-94 (March 2010).

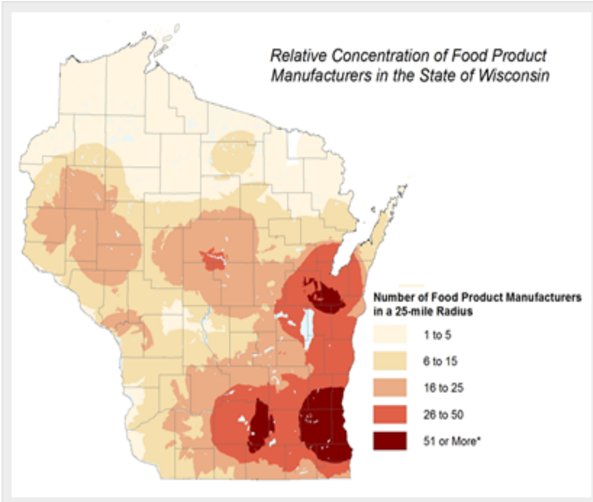
Ethanol has been widely touted as a bio-fuel alternative to fossil petroleum.[57] Indeed, corn ethanol now provides about 10% of all U.S. car fuel.[58] But a lot of fossil energy is needed to grow, harvest, transport and process the corn used to make that ethanol. The net energy balance is improving; but, on average, fossil energy inputs still offset about half the energy provided by corn ethanol.[59]

Producing car fuel on the world's best farmland also poses big dilemmas, including "food vs. fuel," "cars vs. livestock" and "cars vs. soil and water conservation" dilemmas. Emerging technology may make it possible to produce ethanol from alternative materials, such as switch grass or woody brush, that can be grown on more marginal land with fewer inputs and less erosion; but there are many obstacles to viable commercial production.

Food and the Wisconsin Economy

Agriculture and food processing are important to Wisconsin's economy. While other industries suffered during the recession that began in late 2007, Wisconsin agriculture generally benefited from strong world demand and high commodity prices (although prices have retreated lately).

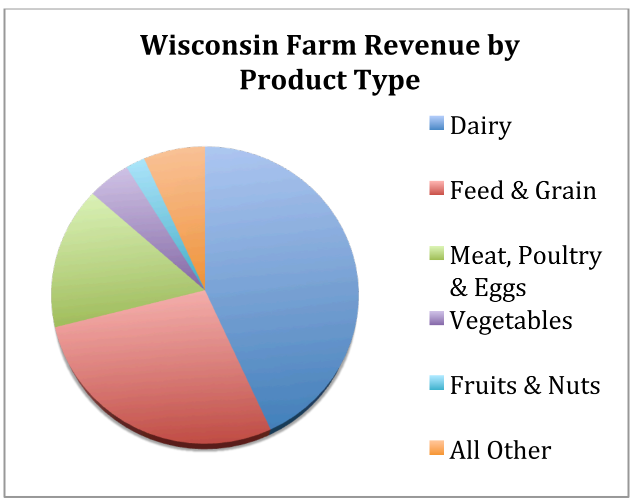
Agriculture and food processing contributed $88 billion to Wisconsin's economy in 2012 (up from $60 billion in 2007), and provided 12% of the state's jobs (up from 10% in 2007).[60] Much of that contribution came from farm supply and wholesale food processing activities, not just farming. Farming itself accounted for about $20.5 billion (less than one-fourth) of the $88 billion total.



Agriculture, farm supply and wholesale food processing activities contributed $88 billion to Wisconsin's economy in 2012, up from $60 billion in 2007. Farming itself accounted for about $20.5 billion (less than one-fourth) of the $88 billion total.

Map: UW-Extension (2009)

Wisconsin food industries depend heavily on livestock. The dairy industry alone generated over $43 billion in economic activity in 2012.[61] Wisconsin is the nation's 2nd leading milk producer, and leads the nation in cheese manufacturing.[62] Meat and poultry processing (including beef from culled dairy animals) is the state's 4th largest manufacturing industry.[63] Most of Wisconsin's farm revenue comes from the production of milk, meat and livestock feed (including grain and forage crops). Of course, livestock producers also *buy* feed, so high feed prices (which help grain producers) can hurt their bottom line.



Wisconsin food industries depend heavily on livestock. Most of our farm revenue comes from milk, meat, poultry, and livestock feed (including grain and forage crops).

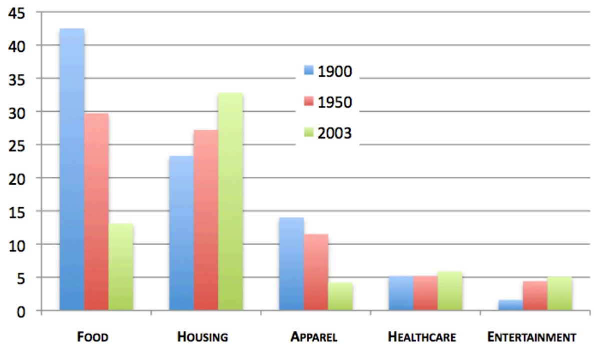
Chart based on USDA-NASS statistics, 2012.

Wisconsin grows 57% of the nation's cranberries, and is among the nation's top producers of corn, potatoes, livestock forage crops (such as alfalfa) and processed vegetables (such as snap beans and sweet corn).[64] Wisconsin has a major brewing industry, and we are a national leader in value-added products such as artisan cheese, craft beer, specialty meats and organic food.

In Wisconsin, as elsewhere, there is growing consumer and community interest in "local food." But at this moment, "local food" accounts for just a fraction of what we eat. Direct farm-to-consumer sales account for *less than half of 1%* of all U.S. agricultural sales,[65] and Wisconsin is steadily losing farmland near its population centers.[66] For most of the year, we get our fresh fruits and vegetables from warmer places. Despite our worthy "local food" aspirations, there has been a broad overall trend toward "de-localization" of our food system.

A Changing Food System

The average U.S. household now spends about 10% of its annual budget on food, compared to over 40% in 1900.[67] By contrast, non-industrialized countries spend nearly *half* of their household income on food (the percent varies by country).[68]



U.S. Household Spending

> *Industrialized food production has helped the U.S. feed a growing population at reduced per capita cost. But large enterprises now dominate our food system.*

Chart courtesy of *The Atlantic* (April 5, 2012). In this chart, household healthcare costs do not include government-paid or employer-paid health insurance benefits.

Industrialized food production has helped us feed a growing population at reduced *per capita* cost. It has also brought us convenience, and a wide array of food products. The average U.S. supermarket now carries more than 42,000 items from all over the world.[69] But farmers and consumers are now tied to a concentrated food system in which large global enterprises play a commanding role. That can affect Wisconsin's economy and environment, for better or worse. The pork industry is a case in point:

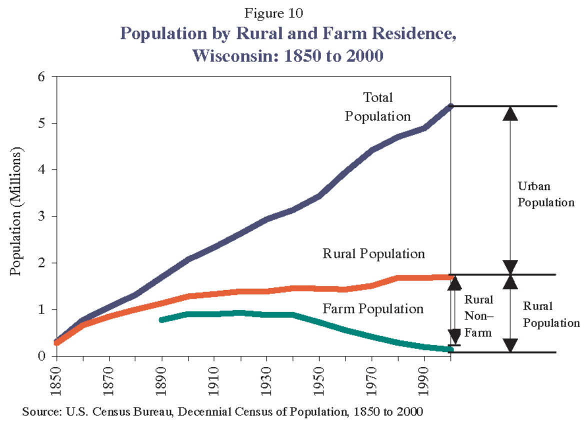
- Just 4 companies slaughter nearly 70% of all U.S. hogs.[70] The largest (Smithfield) is Chinese, and the 3rd largest (JBS) is Brazilian.[71] JBS proposes to buy the 4th largest (Cargill Pork Packing), which would further increase concentration and bring half the U.S. pork industry under foreign control.[72]
- Plants that slaughter over a million hogs per year (per plant) now supply 95% of the U.S. market (compared to 27% in 1976).[73] A single North Carolina plant slaughters 8 million hogs a year.[74]
- Just 100 farm operators – mainly located near processing centers in western Iowa, southwestern Minnesota and North Carolina – now raise over half of all U.S. hogs. Each raises *at least* 50,000 hogs a year.[75]
- The total number of U.S. hog farms fell by 90% in just 30 years, from 1980 to 2010.[76]
- In Wisconsin, small hog farms nearly disappeared when processing facilities were consolidated near more intensive hog production areas in other states.[77]

Our food now comes from fewer, bigger, and more highly specialized farms. Just 2% of U.S. farms now account for well over 50% of all U.S. farm product sales.[78] More than half of the farms with annual gross sales under $350,000 are operating at a loss.[79] Most farm household income now comes from *off-farm* sources,[80] and fewer than half of all farm operators consider farming to be their primary occupation.[81]

The share of our population that lives on farms has been falling for well over a century. In the mid-1800's, nearly 70% of Wisconsin residents lived on farms (and produced their own, very "local" food).[82] But Wisconsin's farm population fell to 35% by 1920, to 10% by 1970, and to less than 2% (including "hobby farms") by the start of the 21st Century.[83]

Farm families now constitute only 8% of Wisconsin's *rural* population;[84] and they, like urban residents, buy their food at supermarkets, convenience stores and fast-food restaurants. Today, Wisconsin has only 10,000 dairy farms, compared to 140,000 in 1950.[85] "America's Dairyland" now has over twice as many *prisoners* as dairy farm operators.[86]

In Wisconsin, just 13% of farms now account for 76% of farm product sales and 43% of all farmland.[87] The average Wisconsin farm operator is over 57 years old, and absentee owners now control 34% of all Wisconsin farmland.[88] These trends have had a huge impact on rural communities, and they are likely to affect farm conservation in the years to come.



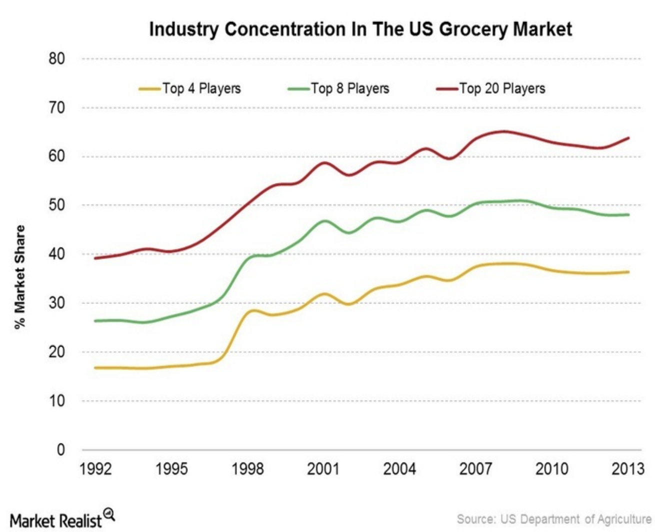
Just 13% of Wisconsin farms now account for 76% of Wisconsin farm product sales, and operate 43% of all Wisconsin farmland. Absentee owners now control 34% of Wisconsin farmland. Farm families constitute less than 8% of Wisconsin's RURAL population.

Chart: Wisconsin Bluebook, 2003-04.

Market Power

Today, few consumers produce even a tiny fraction of their own food; and few farmers sell food directly to consumers.[89] Farmers *and* consumers depend on a vast "food pipeline" that includes commodity dealers, trade brokers, slaughter plants, dairy plants, food processing plants, grain warehouses, food storage facilities, railroads, trucking networks, wholesale distributors, and retail food chains. Industrial networks also supply farmers with seed, fertilizer, pesticides and other inputs. Many of these networks have a global reach, and are now dominated by a handful of global players.

In today's food system, big companies shape food production practices right down to the farm level. The top 4 food retailers (led by Wal-Mart) now control nearly 40% of the U.S. grocery market, compared to just 17% in 1992.[90] They buy from a limited number of favored suppliers, and their procurement demands affect the entire food system. Leading fast-food chains (like McDonald's) cast an equally long shadow, as do their beef and poultry suppliers (like Tyson's). Restaurants now claim 50% of our retail food dollars, compared to just 25% in 1955.[91]



The food industry is increasingly concentrated. For better or worse, major food companies shape food production practices right down to the farm level.

Concentration in the U.S. Retail Grocery Market (1992-2013).

Chart: USDA, reproduced by Market Realist

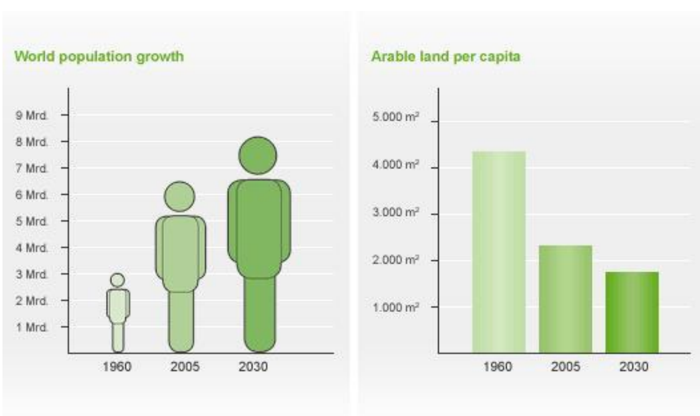
Concentration extends to the genetic foundation of our food supply. Just 2 companies (Monsanto, DuPont, and entities they control) now supply about 70% of all U.S. corn seed (up from 45% in 2004) and 60% of all U.S. soybean seed (up from 40% in 2004).[92] They also hold patents on most of the seed sold by their competitors.[93] Patents (and corn hybridization) prevent farmers from reproducing seed, as they once did.[94] In 1982, soybean farmers still produced 50% of their own seed; today, they produce almost none.[95] Farmers are now mostly captive seed buyers, rather than independent seed producers.

Meanwhile, the steady consolidation of food processing industries has transformed whole sectors of the farm economy (the pork industry is just one example). Many food processors procure farm products under advance contracts with chosen farmers, rather than in open market transactions. The contracts often control farming practices in great detail. Processors use contracts to drive down their supply costs, minimize their financial risks, and tailor farm products to fit their processing, marketing, food safety and "public image" needs (including, potentially, their animal welfare and environmental "image" needs). Farmers who want a contract must meet processor specifications. Contract requirements may affect farming methods for better or worse.

Food and Land

Agriculture uses more land than any other human activity, so it naturally has a big impact on the environment. Nearly 40% of the world's land area is now devoted to agriculture, compared to just 7% in 1700.[96] Even so, farmland availability has not kept pace with exploding world population and food demand. Nearly all of the world's useful farmland is already under production, and further conversion of marginal lands (such as rain forest, wetlands, and dry grassland) will come at great expense to the environment. There will be no more "new" continents to exploit. Our future will depend on saving what we have, and using it wisely.

Today, the world has only *half as much farmland per capita* as we did just 50 years ago.[97] That *per capita* loss is mainly due to a doubling of world population. But good farmland is also being lost to development, drought, erosion, salinization, declining fertility, over-grazing and environmental degradation. The U.S. is no exception. In less than 3 decades, from 1982 to 2010, more than 24 million acres of U.S. farmland were lost to development alone.[98] That is equivalent to nearly 70% of the total land area of Wisconsin.



Source: FAO

Today, the world has only half as much farmland per capita as it did just 50 years ago. In less than 3 decades, the U.S. lost more than 24 million acres of farmland to development. That is equivalent to nearly 70% of the total land area of Wisconsin.

Chart: United Nations (FAO).

About 40% of Wisconsin's total land area is still devoted to farming, not counting forest production.[99] But Wisconsin has been losing 20-30 thousand acres of farmland *each year*, mainly to development.[100] That includes some of the best farmland in the state.[101] All told, over 777 thousand acres of Wisconsin rural land (including over 520 thousand acres of farmland) were converted to development from 1982 to 2007.[102] That is an area the size of Dane County.

Wisconsin has been losing over 20 thousand acres of farmland each year. From 1982 to 2007, over 777 thousand acres of Wisconsin rural land (including 520 thousand acres of farmland) were converted to development. That is an area the size of Dane County.

Map: Wikimedia

Despite growing food demand, Wisconsin is targeting substantially *less* farmland for preservation than it did in the 1980's.[103] Land use conflicts are growing as farms become more industrialized, as sprawling "checkerboard" development turns unbroken stretches of farmland into disjointed scraps, and as more homes are located near large-scale farming operations. Some farm operators are finding it hard to expand and modernize, because suitable land is in short supply.

Food and Water

Agriculture is a huge consumer of water, as well as land. In fact, agriculture accounts for up to 80% of consumptive water use in the U.S.[104] In western states, which rely heavily on irrigation, water shortages have reached crisis proportions. In California, which accounts for 12% of all U.S. farm production,[105] some of the world's best farmland is now being idled by drought. California groundwater levels have dropped by 30 million acre-feet in the last 3 decades, as farmers have pumped more water to meet growing food and specialty crop demands (including rapidly growing Asian demand).[106]

Almonds are a widely cited example. California now produces 82% of the *world's* almonds.[107] Almonds – a favorite of health-conscious consumers – are the state's second leading crop by acreage, and first by export value.[108] About 600 gallons of water are needed to grow just *one pound* of almonds.[109] As surface water irrigation sources have dwindled, much of that water has been pumped – essentially free of charge – from underground aquifers.[110] Despite groundwater depletion and drought, California farmers have responded to surging world demand by *doubling* their water-intensive almond production over the last decade.[111]

In a sense, California is mining its water reserves and sending them elsewhere in the form of food. All told, California may now be "exporting" about 500 gallons of "virtual" water per resident per day.[112] Some aquifers may require thousands of years to replenish, if they can be replenished at all.

The same problem exists, on an even larger scale, in the historic "Dust Bowl" region of the southern plains – where agriculture now depends on irrigation water pumped from the great Ogallala aquifer. The water now being pumped from the Ogallala began its underground journey over 10,000 years ago, at the end of the last Ice Age.[113] At current pumping rates, the great aquifer – which took thousands of years to fill – will be largely depleted within 30 years.[114]

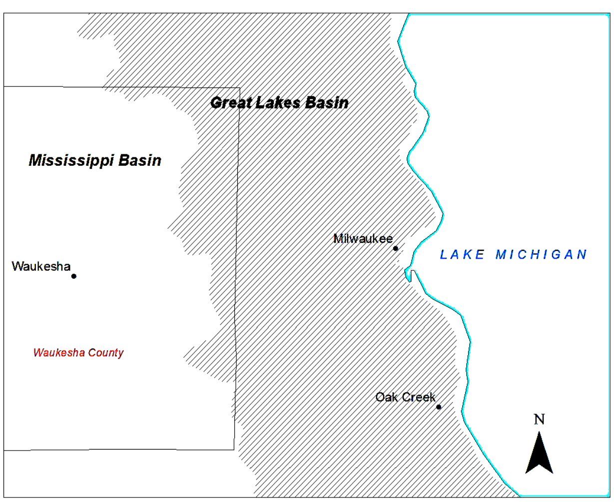
Wisconsin has abundant water compared to California and the southern plains, and we are less dependent on irrigation. But irrigation is important in Wisconsin's Central Sands region, which accounts for most of our high-value potato, vegetable and cranberry production, and a significant share of our grain and dairy production. In the Central Sands, crop irrigation and new dairy operations have contributed to a rapid proliferation of high capacity wells.

Agriculture is, by far, the nation's biggest water user. Wisconsin has abundant water compared to many states, and we are less dependent on irrigation. But irrigation is important in some areas, such as the Central Sands, where the rapid growth of high capacity wells is affecting groundwater and surface water levels.

Map courtesy of the Natural Resources Foundation of Wisconsin

The Central Sands region now has over 3,231 high capacity wells of various kinds, compared to only 100 in the 1950's.[115] High capacity wells are now having a significant cumulative impact on groundwater and surface water levels, including lake and trout stream levels.[116] But agriculture is only part of the problem. Urban development is also putting stress on groundwater supplies, in the Central Sands and elsewhere.[117]

In Waukesha County, an explosion of urban development has depressed groundwater levels and degraded groundwater quality, to the point that the City of Waukesha and surrounding suburbs now want to import drinking water from Lake Michigan.[118] Over 40 million people already depend on the Great Lakes for drinking water.[119] But Waukesha's situation is complicated because – like many other thirsty locations in the U.S. – the city lies *outside* the Great Lakes watershed. The Waukesha case is a reminder of the potentially huge demands on our Great Lakes, one of the world's most important fresh water resources.



Rapid urban development has depleted groundwater in Waukesha, which now wants to import drinking water from Lake Michigan. But, like many thirsty locations in the U.S., Waukesha and its suburbs lie OUTSIDE the Great Lakes watershed.

The Waukesha case reminds us of the potentially huge demands on our Great Lakes, one of the world's most important fresh water resources.

Map courtesy of Kaye LaFond, Circle of Blue

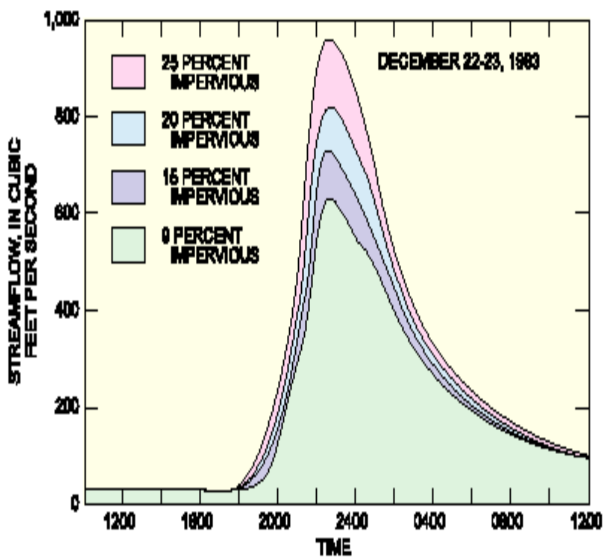
While some Wisconsin communities face groundwater shortages, many communities contend with *too much* water in the form of surface runoff – especially after major storm events. Storm water management has become a serious and hugely expensive problem throughout Wisconsin. The problem is aggravated by suburban sprawl, farmland loss, and a recent pattern of heavier storms (possibly related to global warming).

Storm water management has become a big problem throughout Wisconsin. The problem is aggravated by suburban sprawl, farmland loss, and a recent pattern of heavier storms.

Waukesha-Milwaukee Flood Event (2009).

Image: National Weather Service Forecast Office

Farms, forests and wetlands play an important role in absorbing rainfall, replenishing groundwater, and mitigating floods. As those lands are converted to urban and suburban uses (impervious roofs and pavement), destructive surface runoff and flooding problems will grow.[120]

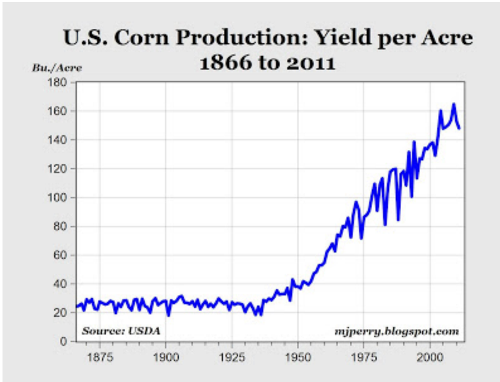


Farms, forests and wetlands absorb rainfall and mitigate floods. As those lands are converted to urban and suburban uses (impervious roofs and pavement), destructive runoff and flooding problems will grow.

U.S. Geological Survey computer simulation shows how storm water discharges increase when impervious surfaces (roofs and pavement) cover more of a watershed.[121] Local hydrology varies.

Intensive Crop Production

Despite a rapidly shrinking *per capita* land base, farmers have met soaring crop demand by producing far more *per acre* of land. Since 1930, for example, average U.S. corn yields have risen from under 30 bushels per acre to over 160 bushels per acre (some farms can now produce well over 200 bushels per acre).[122] The U.S. now produces *5 times more corn* than it did in 1950, on roughly the same acreage.[123] The increase comes from high-yield genetics, hybridization, close uniform planting, mechanization, irrigation, geographic specialization, and extensive use of fertilizers and pesticides, among other things.



> *Despite a shrinking per capita land base, farmers have met soaring crop demand by producing far more per acre of land.*
> *But the push for higher crop yields has had environmental side effects.*

Chart: USDA, reproduced by mjperry.blogspot.com

High crop yields come at a cost. Farmers (and their bankers) consider the cost of prime farmland, premium patented seed, state-of-the-art machinery, irrigation systems, fertilizer, pesticides, and other yield enhancing inputs for which farmers must pay market prices. But intensive, high-yield production has other costs that are not captured in farm financial statements. Consider the following "hidden" costs that affect us all:

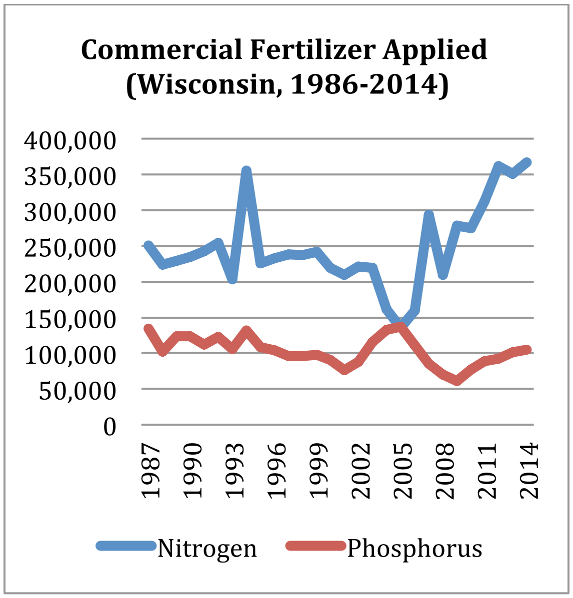
- Added crop nutrients (nitrogen and phosphorus) are the most widespread pollutants of our lakes and streams.[124]
- Nearly 34% of Wisconsin's private drinking wells contain detectable pesticide residues.[125]
- 20-30% of private drinking wells in Wisconsin's heavily farmed areas contain nitrates in excess of the state's enforcement standard.[126]
- Crop irrigation is drawing down groundwater and surface water levels in some parts of Wisconsin.[127]
- Unbroken plantings of genetically uniform crops are reducing bio-diversity, eliminating important pollinators, and increasing systemic vulnerability to pests and disease.[128]
- Routine applications of widely used pesticides are speeding the evolution of tougher crop pests.[129]

Nitrogen pollution

Crop nutrients are at the root of some of our nation's biggest water pollution problems. Crops require key nutrients, including nitrogen and phosphorus. Today's high-yield crop varieties require even more of these nutrients. Some crops, like corn, are especially heavy consumers; and irrigation increases their nutrient appetite. Farmers add nutrients, in the form of commercial fertilizer or manure, to ensure that crops are well fed and produce abundant yields.

Nitrogen fertilizer, first synthesized in the early 1900's, now supplies up to half the nitrogen required by crops worldwide.[130] Without it, the world's food supply and population would collapse.[131] U.S. farmers now apply *five times more nitrogen fertilizer* than they did in 1960.[132] But only part of that nitrogen finds its way to crop roots, even when it is carefully applied with the best technology.[133] Some of the "unused" nitrogen is released to the atmosphere as nitrous oxide, a greenhouse gas;[134] and some is leached to groundwater and surface water as nitrate pollution.[135] A "good" crop nutrient can thus become a "bad" environmental pollutant. Heavy nitrogen applications increase pollution risks.

From 2004 to 2013, Wisconsin farmers more than *doubled* their nitrogen fertilizer applications (*not* counting manure).[136] Much of that nitrogen went to feed bigger corn crops (in 2013, Wisconsin farmers planted 14% more corn acres than they did in 2004).[137] But much of it ended up as greenhouse gas, or in our water.



Commercial fertilizer provides important crop nutrients, including nitrogen and phosphorus. But some of those nutrients end up as pollutants.

Wisconsin farmers more than doubled their nitrogen fertilizer applications over the last decade.

Chart does *not* include manure applications, which also add nitrogen and phosphorus.

Chart based on data from DATCP annual fertilizer sales tonnage reports (less than 5% non-farm).

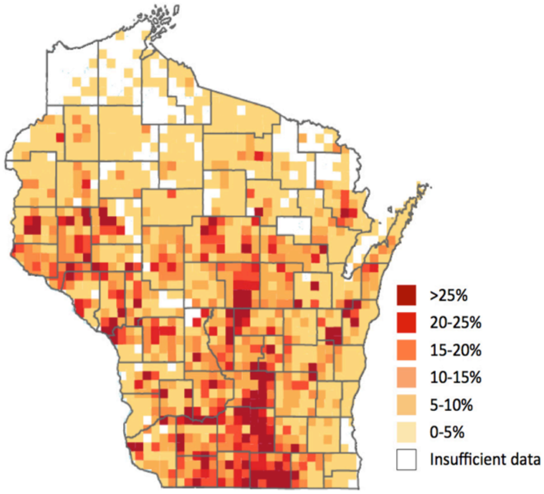
Fertilizer costs money, so farmers have some incentive to conserve.[138] But farmers also want to apply plenty of nutrients to ensure that crops reach their full potential. When crop prices are high relative to nitrogen prices, it usually pays farmers to apply more nitrogen.[139] It also pays to apply more nitrogen to irrigated crops, including those grown on sandy soils that are prone to nitrate leaching.[140]

Even when nitrogen is applied at relatively conservative economic rates recommended by University of Wisconsin agronomists, there can be significant nitrate leaching to groundwater.[141] In one series of studies, UW researchers found that 20% of the nitrogen applied to corn at recommended rates, on prime soil, eventually leached to groundwater.[142] Losses can be *much higher* when farmers (or their fertilizer suppliers) apply at higher rates or under less favorable conditions.[143]

Nitrate contamination is Wisconsin's most pervasive groundwater pollution problem, and it has increased in extent and severity.[144] About 200 million lbs. (100,000 tons) of nitrate enter Wisconsin groundwater each year.[145] There are various natural and human sources, but roughly 90% of the nitrate comes from farms.[146] Nitrate stays in groundwater for years or decades; so concentrations may increase, over time, in deep drinking water aquifers.[147]

Nitrate in drinking water can cause a number of health problems including "blue baby syndrome," a potentially fatal condition that affects infants under 6 months old.[148] At least 9% of all Wisconsin private wells already exceed the state enforcement standard for nitrate, and the rate is much higher in the heavily farmed areas of southern Wisconsin.[149] In those areas, 20-30% of private wells already exceed the enforcement standard.[150] About a third of all Wisconsin families get their drinking water from private wells.[151]

Nitrate contamination also affects community drinking water supplies. In a 2012 survey, 47 Wisconsin communities reported well contamination above the state nitrate enforcement standard (up from 14 in 1999), and 74 communities reported that contamination levels were increasing.[152] As of 2012, Wisconsin communities had spent over $32.5 million on remedial actions.[153] In an Iowa case that is drawing national attention, the Des Moines water utility is now suing farm drainage districts over nitrate contamination of the Raccoon River, the city's drinking water source.[154]



Nitrate, leached mainly from nitrogen-rich farm fields, is Wisconsin's most pervasive groundwater contaminant. Heavy nitrogen applications increase nitrate pollution risks.

Map shows percent of local groundwater samples above state drinking water standard for nitrate (10 mg/L). High concentrations reflect soil, geology, crop and irrigation patterns.[155]

Map: University of Wisconsin-Stevens Point, Center for Watershed Science and Education[156]

Phosphorus pollution

A second major crop nutrient, phosphorus, is also a serious water pollution problem. High levels of nitrogen and phosphorus pose a double-barreled threat to surface water quality – causing lake eutrophication, algae blooms and coastal "dead zones."[157] Phosphorus, in particular, plays a decisive role in the potentially toxic algae blooms that choke lakes throughout Wisconsin.[158] The excess phosphorus comes mainly, though not exclusively, from farm erosion and runoff.[159]

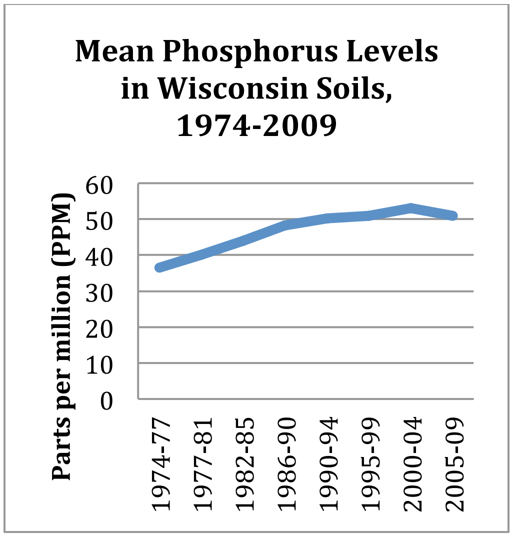
Phosphorus runoff, mainly from farms, plays a decisive role in lake eutrophication and algae blooms.

Split Lake Experiment: Phosphorus added to one side of the lake triggers a heavy algae bloom.

Experimental Lake 226, Ontario, Canada. Whole lake experiment conducted under the auspices of the Fisheries Board of Canada.

Hundreds of Wisconsin watersheds have been classified as "impaired watersheds" under the federal Clean Water Act, because of high phosphorus levels.[160] Urban sewage districts and other "point source" dischargers now face millions of dollars in phosphorus control costs because of high watershed phosphorus levels caused mainly by "nonpoint" farm runoff, which the Clean Water Act does not regulate.[161]

Phosphorus binds to soil particles, so it can build up in the soil over time. Wisconsin's mean soil phosphorus level has been increasing for decades, as a result of regular fertilizer and manure applications (local conditions vary).[162] A relentless tide of soil erosion carries phosphorus to lakes and streams, where it feeds the growth of algae and aquatic weeds. Pollution risks grow when farmers fail to control soil erosion,[163] or when they add unnecessary phosphorus to soils that are already phosphorus-rich.[164] Intensive row cropping and heavy storms make matters worse.



Wisconsin soil phosphorus levels have been rising for decades, due to fertilizer and manure applications (local conditions vary). Soil erosion from farm fields carries phosphorus to lakes and streams, where it feeds algae and weeds.

Pollution risks grow when farmers fail to control erosion, or add too much phosphorus to soils that are already phosphorus-rich. Intensive row cropping and heavy storms make matters worse.

Chart based on University of Wisconsin-Madison Soil Testing Laboratories, *Wisconsin's Historical 5-Year Summary Database.* Since 2009, the last year shown on this chart, annual Wisconsin phosphorus fertilizer applications have nearly *doubled*.

Pesticide pollution

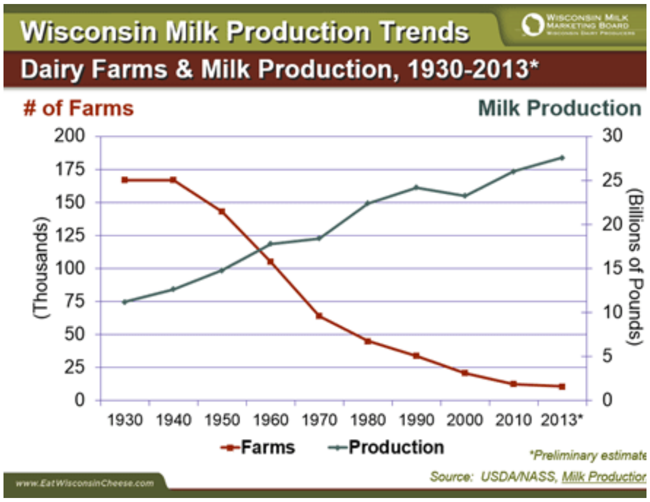
Pesticides, like crop nutrients, are essential for today's high-yield agriculture. But pesticides also pose risks. Farmers minimize those risks by applying pesticides according to federally approved labels and state rules.[165] But unforeseen problems can sometimes occur. Atrazine is a case in point.

For nearly 40 years, atrazine was the nation's most widely used corn herbicide. Farmers applied atrazine, year in and year out, per label directions. Few suspected that the herbicide might be contaminating groundwater. But beginning in the 1980's, tests on 13,000 Wisconsin drinking water wells showed that 40% of the tested wells were contaminated with atrazine or its metabolites (including 8% above state enforcement standards).[166] Contamination levels fell only after Wisconsin banned atrazine use on more than a million acres, and restricted application rates statewide.[167] Other pesticides have also been found in groundwater.[168] In fact, nearly 34% of all Wisconsin wells contain detectable residues of one or more pesticides (alachlor and metolachor are now the most frequently found).[169]

"Roundup-Ready" GMO corn helped to alleviate the atrazine problem, because it allowed farmers to use glyphosate ("Roundup") herbicide without damaging corn plants.[170] Glyphosate, which is not prone to groundwater leaching, soon replaced atrazine as the dominant corn herbicide. But the GMO revolution had other effects: About 90% of U.S. corn and 93% of U.S. soybeans now contain patented GMO traits (especially the "Roundup-Ready" trait),[171] and ingredients from those crops are now found in over 70% of U.S. processed foods.[172] By inserting patented GMO traits (just 1 or 2 genes) into seeds containing *thousands* of ancient genes, seed companies tightened their proprietary grip over the (once public) corn and soybean gene pool.[173] Widespread use of glyphosate also hastened the spread of aggressive, glyphosate-resistant weeds that require additional pesticide applications.[174]

Intensive Livestock Production

Livestock production, like crop production, has undergone a profound revolution. Specialized breeding, automation, scientific feeding, antibiotics,[175] production-enhancing pharmaceuticals,[176] industrial-style management, and economies of scale have dramatically increased production efficiency. Today, for example, Wisconsin has 40% *fewer* dairy cows and 93% *fewer* dairy farms than we did in 1950; yet we produce 80% *more* milk.[177] Milk production per cow has *tripled* since 1950, and there is no end in sight.[178] But the production revolution has had an unsettling impact on farms and rural communities, and has deeply affected our relationship to farm animals and the environment.

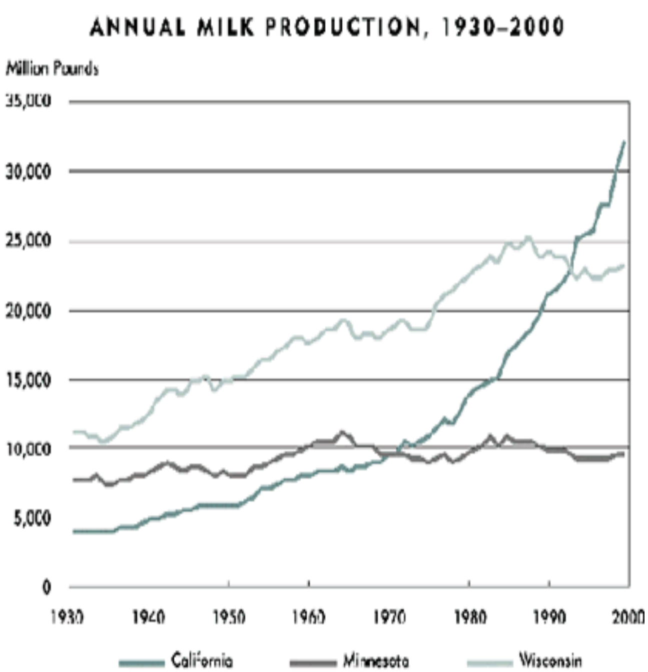


A production revolution has profoundly altered the U.S. livestock industry. Today, Wisconsin has 40% fewer dairy cows and 93% fewer dairy farms than we did in 1950, yet we produce 80% MORE milk. Milk production per cow has TRIPLED, and there is no end in sight.

Chart: Wisconsin Milk Marketing Board, based on USDA-NASS.

Large confinement facilities now account for much of our nation's beef, pork, poultry, egg and dairy production. These facilities, which often house thousands of closely confined animals, are designed to produce large quantities of a commercially uniform product in the shortest possible time, at the lowest possible per-unit cost.[179] Today, a 5.3 lb. chicken can be produced in 35 days on about 8 lbs. of feed.[180] Thirty years ago, it took over 7 lbs. of feed to produce a 3 lb. chicken in the same time.[181]

California pioneered industrial-scale dairy farming in the 1980's, and by 1994 it rocketed past Wisconsin to become the top U.S. milk producing state. California now produces *50% more milk* than Wisconsin, even though Wisconsin has 5 times more dairy farms than California.[182] The average California dairy farm has over 1,000 cows, compared to just 124 in Wisconsin.[183] But Wisconsin is moving in California's direction. Wisconsin now has about 300 dairy CAFOs (herds with more than 700 cows),[184] and our largest CAFO has about 8,000 cows.[185] CAFOs comprise just 3% of Wisconsin dairy herds, but now produce 30% of Wisconsin's milk.[186]



California pioneered industrial-scale dairy farming in the 1980's, and soon rocketed past Wisconsin as the top U.S. milk producing state.

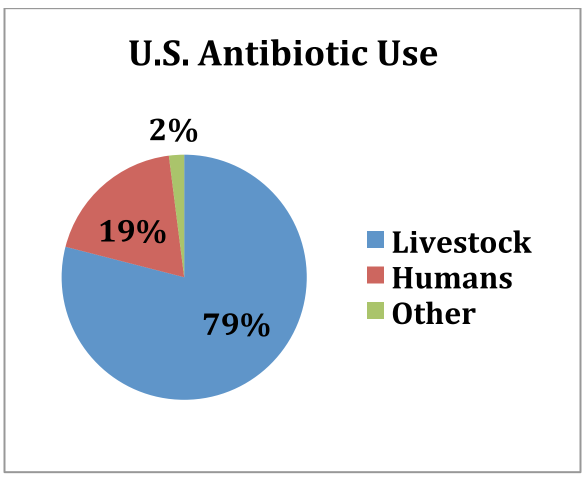
Wisconsin output fell briefly, but is now growing again – partly because of larger dairy herds. Just 300 CAFOs (3% of Wisconsin dairy farms) now produce 30% of Wisconsin's milk.

Chart: USDA

Modern livestock production is a "high wire act." The performance is stunning; but there is little room for error, and the risks are palpable. Large facilities require capital investments that are impossible for many farmers. Heavy animal waste concentrations pose new health and environmental threats. Animal confinement practices (especially in the pork and poultry industries) have raised contentious animal welfare issues. And crowded populations of genetically uniform animals can be easy targets for disease.[187]

The livestock industry now accounts for nearly 80% of all U.S. antibiotic use.[188] North Carolina *alone* uses more antibiotics on livestock (mainly swine and poultry) than our entire nation uses on humans.[189] According to the U.S. Centers for Disease Control (CDC), this heavy antibiotic use is speeding the evolution of drug-resistant pathogens.[190] Livestock operators use antibiotics to treat and prevent disease; but in some livestock sectors, operators also feed antibiotics on a routine basis to promote animal growth – a practice that CDC opposes.[191]

Antibiotics are *not* routinely fed to dairy cows, but are used to treat common conditions like mastitis. Farmers may not ship milk from cows that are undergoing treatment.[192] Wisconsin dairy plants must test for a range of antibiotic residues, and must discard tainted milk (the farmer incurs the loss).[193] The amount of discarded milk has fallen steadily over the past 5 years, from 7.87 million pounds (2010) to 4.44 million pounds (2014), even as Wisconsin's total milk production has grown.[194] Discarded milk represents less than 1/10 of 1% of all Wisconsin milk production.



The livestock industry accounts for nearly 80% of all U.S. antibiotic use. Routine antibiotic use can speed the evolution of drug-resistant pathogens, which can threaten animal and human health.

Chart based on use estimates cited in Hollis and Ahmed, "Preserving Antibiotics, Rationally," New England Journal of Medicine (December 26, 2013).

When things go wrong in a large, integrated livestock production system, they can go wrong in a big way. That was illustrated in 2015, when a deadly bird flu virus ravaged the Upper Midwest poultry industry.[195] The flu strain was carried to the U.S. by wild migratory birds. Despite standard biosecurity precautions, the disease entered large poultry facilities (some housing *millions* of birds) and spread rapidly among the closely confined and genetically homogeneous fowl. Normal supply and distribution networks became potential highways for further spread between facilities.[196]

By the time the bird flu epidemic subsided in June 2015, nearly 50 million chickens and turkeys had died or been killed to prevent further disease spread.[197] Millions of birds were "composted in place" in the facilities where they died, because there were few other disposal options. The disease cost nearly $1 billion and 6,000 jobs in Iowa alone (farm operator losses were partly indemnified by U.S. taxpayers).[198] Other states, including Minnesota and Wisconsin, were also hit hard. U.S. egg prices rose dramatically, and at least 75 nations restricted imports of U.S. poultry products. Some poultry operators lost up to 5 million birds each.

Modern livestock production can be a "high wire act." In 2015, a deadly bird flu virus ravaged the Upper Midwest. The disease spread quickly among large poultry facilities (some housing millions of birds). Nearly 50 million chickens and turkeys died. The disease cost nearly $1 billion and 6,000 jobs in Iowa alone. Losses were partly indemnified by U.S. taxpayers.

A Bird Flu Victim.

Photo: Dr. D. Swayne, USDA. Reproduced courtesy of the Center for Public Health and Food Security, Iowa State University

Although this particular bird flu strain did not threaten humans, other strains have been known to cause dangerous human flu epidemics. The outbreak reminds us that we do not, and cannot, live in a "hermetically sealed package." Our food system is part of an infinitely complex biological world; and, like our financial system, it is subject to many unpredictable risks.[199] In biology, as in finance, diversification is a hedge against risk. When we "put all of our eggs in one basket," we may be asking for trouble.

America's Dairyland: Milk and Manure

Wisconsin turned to dairying in the late 1800's, after wheat monoculture had exhausted the state's virgin soils. Dairying offered environmental, as well as economic advantages. Dairy forage crops and pasture provided better erosion control, and helped to restore soils exhausted by "cash grain" monoculture. Dairy cows also provided two valuable commodities on a daily basis: milk and manure. Nutrient-rich milk fed families, and nutrient-rich manure helped to rejuvenate tired farm soils.

Cows could eat grass and other plant material that humans could not digest. The cows extracted nutrients like nitrogen and phosphorus, and used some of those nutrients to make milk. The cows also returned lots of nutrients and organic matter to the farm soil in their manure. By 1915, Wisconsin was the nation's leading dairy state,[200] and cows were producing a steady supply of organic fertilizer for Wisconsin crops.

Small dairy farms were once the bedrock of rural Wisconsin. Farm families kept only as many cows as they could milk by hand, and feed from their own farms. As late as 1950, the average Wisconsin dairy farm had just 15 cows.[201] In 1950, Wisconsin had far more cows than it does today;[202] but the cows were smaller, and produced less milk and manure per cow. They also deposited manure on 140 thousand farms compared to just 10 thousand today,[203] so manure was more evenly distributed around the state.

Emerson Brooks Papers.
Special Collections, National Agricultural Library.

In 1950, Wisconsin had 140 thousand dairy farms compared to 10 thousand today, and the average dairy farm had just 15 cows. Today, manure production is far more geographically concentrated.

Image: USDA, National Agricultural Library

After World War II, everything changed. Rural electrification, powerful farm machinery, automated milking, bulk milk handling and transportation, high production genetics, scientific feeding, and intensive farm management transformed the dairy industry. Forward-looking dairy farmers had strong economic incentives to expand, and they did. Wisconsin produced more milk on bigger, more efficient farms, even as farm numbers declined.

Wisconsin milk production grew steadily until the last decade of the 20th Century. But then it stalled in the face of discontinued federal price supports and powerful low-cost competition from California – a state that had taken dairy industrialization to a whole new level.[204] Wisconsin's decline lasted nearly a decade, and our famous cheese industry was at risk. But we eventually regained our competitive footing, partly by scaling up our farms to meet California's industrial dairy challenge. Drought and higher feed costs also reduced California's initial cost advantage.[205]

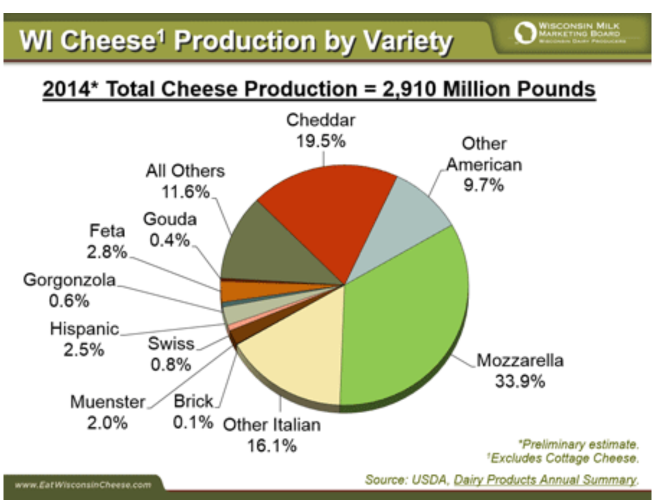
More Milk, Cheese *and* Manure

Today, Wisconsin is producing more milk than ever before. We now produce nearly 28 billion pounds of milk a year – a 25% increase in just 10 years.[206] Wisconsin agricultural leaders have announced a goal of 30 billion pounds by 2020.[207] Higher milk production has boosted our cheese industry, which needs an ample milk supply in order to grow and stay competitive.

Wisconsin is now producing more milk than ever before, on bigger and more efficient farms. We now produce nearly 28 billion pounds of milk a year – a 25% increase in just 10 years. Higher milk production has boosted our cheese industry.

Photo: UW-Madison, Center for Integrated Agricultural Systems

Ninety percent of Wisconsin's milk goes for cheese, and 90% of that cheese is consumed outside the state.[208] Wisconsin cheese production grew by nearly 21% over the last decade, reaching 2.9 billion lbs. in 2014.[209] Wisconsin is America's top cheese state, producing 26% of all U.S. cheese.[210]



Ninety percent of Wisconsin's milk goes for cheese, and 90% of that cheese is consumed outside the state.

Wisconsin cheese production grew by nearly 21% over the last decade.

Wisconsin is America's top cheese state, producing 26% of all U.S. cheese.

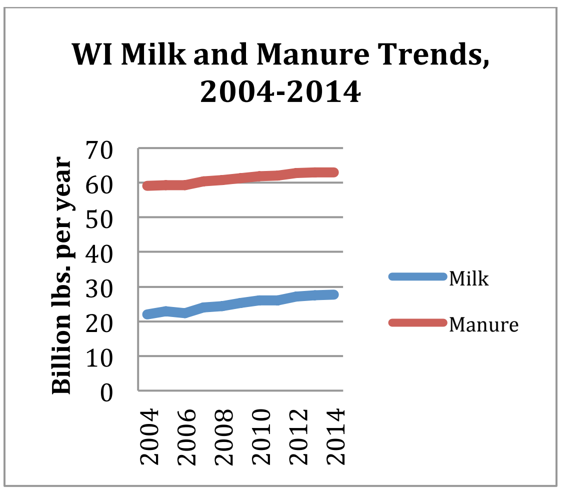
Chart: Wisconsin Milk Marketing Board, based on USDA-NASS.

Wisconsin leads the nation in artisan cheese production (specialty cheeses now comprise 23% our total cheese output).[211] But the vast majority of our cheese goes for mass-market uses, such as pizza. Many competitors make mass-market cheese, and would love to grab Wisconsin's slice of the pie. Competing dairy ingredients come from as far away as New Zealand.

Wisconsin leads the nation in artisan cheese; but most of our cheese goes for mass-market uses, such as pizza. Many competitors would love to grab Wisconsin's slice of the pie.

Photo: Scott Bauer, USDA-Agricultural Research Service, Image K7633-3 (via Wikimedia Commons, public domain)

As Wisconsin produces more milk and cheese, it also produces more manure. Wisconsin cows now produce roughly 64 billion pounds of manure (feces and urine, as excreted) each year[212] – about 7% more than a decade ago.[213] Manure is still a valuable fertilizer, but it has become a serious environmental challenge in some places.

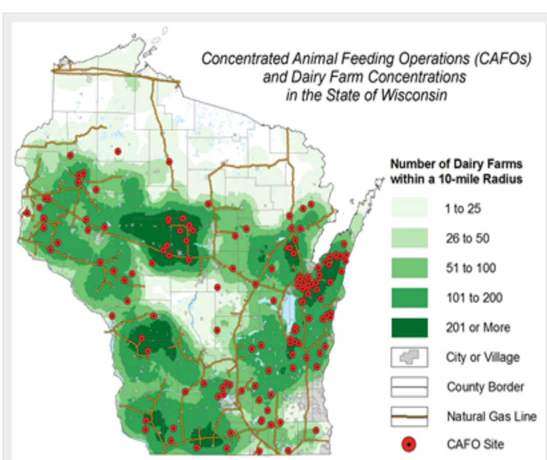


More milk means more manure. Manure is still a good fertilizer, but it has become a serious environmental challenge in some places.

Chart: Wisconsin manure estimate based on a Holstein cow regression equation (Weiss, 2004), using Wisconsin cow numbers and average milk per Wisconsin cow (USDA statistics).[214] This calculation conservatively includes lactating cows and dry cows, but not replacement heifers or calves.

A similar calculation using an ASABE (American Society of Agricultural and Biological Engineers) formula yields comparable figures, especially for recent years.[215] The ASABE formula yields higher manure totals (about 64.5 billion lbs. in 2014, compared to 63 billion lbs. using the Weiss formula), but a slower rate of growth over the period 2004-20

Dairy growth has been focused in certain areas, and has been especially strong near cheese manufacturing hubs in northeastern Wisconsin. In high growth areas, manure concentrations are becoming more acute.



Dairy growth has been focused in certain areas, and has been especially strong near cheese manufacturing hubs in northeastern Wisconsin. In high growth areas, manure concentrations are becoming more acute.

Map: UW-Extension (2009)

Some dairy growth areas have unique environmental problems, such as shallow karst bedrock that can allow direct manure runoff to groundwater. Dairy growth is also colliding with suburban sprawl in some places. More manure is being spread on less land, often near homes and drinking wells.

Some dairy growth areas have shallow karst bedrock that can allow direct manure runoff to groundwater. Dairy growth is also colliding with suburban sprawl in some places. More manure is being spread on less land, often near homes and drinking wells.

Shallow Karst Bedrock Areas

Map courtesy of the Wisconsin Geological and Natural History Survey

Managing Manure

Today's dairy farms are concentrating bigger cow populations in year-around confinement facilities, rather than on pasture. The cows eat lots of nitrogen-rich and phosphorus-rich feed, transported from distant locations. Some operators add more phosphorus to feed, to improve cow reproductive performance. Not surprisingly, the cows produce big pools of manure that are rich in nitrogen, phosphorus and other potential water pollutants. In some cases, the manure may also contain pathogens that can threaten livestock or (more rarely) human health.[216] As dairy farms get bigger, they create larger local pools of manure.[217]

In some ways, today's large dairy farms resemble human cities. And like human cities, they pose special waste management challenges. A 1,000 cow dairy herd produces about as much fecal waste (total solids, BOD, nitrogen and phosphorus equivalents) as a city of 25 or 30 thousand people (think Neenah, Stevens Point, Superior, Sun Prairie or West Bend).[218] But dairy waste, unlike human waste, is typically spread on land in untreated form (there are some exceptions).[219] In most areas, the soil can safely assimilate the waste – but only if it is not overloaded.

A 1,000 cow dairy herd produces about as much fecal waste as Stevens Point, a city of 25,000 people. Dairy waste is typically spread on land in untreated form. In most areas, the soil can safely assimilate the waste – but only if it is not overloaded.

Aerial View of Stevens Point.

Image: www.ViewFromAbove.com, use courtesy of View From Above…Aerial Photography

Modern dairy farms collect, store and apply manure in liquid form.[220] Automated systems collect the excreted manure (feces and urine), together with milking parlor wash water and other diluting materials. Dilution reduces the *concentration*, but not the total *quantity*, of nitrogen and phosphorus in the liquid manure. Dilution adds weight and volume, making the manure more expensive to store and haul.[221]

Liquid manure is kept in large storage tanks (or in-ground "lagoons") until it can be applied. At least 10 million gallons of storage capacity are normally needed for 1,000 cows for one year.[222] Without adequate planning and investment, herd expansions on farms of all sizes can outrun manure storage capacity.[223] Farmers with inadequate storage capacity may be forced to spread manure when runoff risks are high (especially in winter). Spills from overflowing or defective storage facilities can also cause acute pollution discharges and fish kills (there were 38 recorded spills in 2013).[224]

Liquid manure is kept in large storage tanks (or in-ground "lagoons") until it can be applied. At least 10 million gallons of storage capacity are normally needed for 1,000 cows for one year. Farmers who lack adequate storage capacity may be forced to spread manure when runoff risks are high (especially in winter).

Dairy Manure Lagoon - California

Image: University of California-Davis

Even under optimal conditions, safe manure disposal requires an adequate land base. A 1,000 cow dairy operation may need well over 2 thousand acres of land for safe manure spreading (circumstances vary).[225] Some dairy operators may struggle to find enough "spreadable" acreage. In some places, where surging manure production is coming up against suburban sprawl and fragile environments, dairy operators and their neighbors may be confronting a manure disposal crisis.

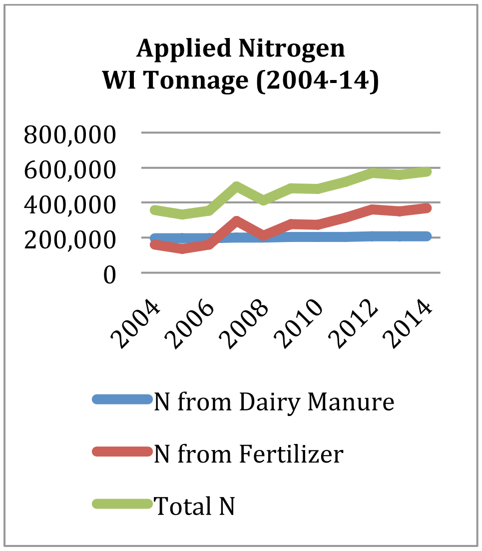
As local application sites get harder to find, dairy operators or their hired commercial haulers must haul manure over longer distances. A dairy operation with 1,000 cows must haul about 12 million gallons of liquid manure a year,[226] and some operators now haul manure as far as 60 miles.[227] Manure is heavy, and hauling is expensive, so there can be a tendency to apply too much manure on nearby fields.[228] That increases water pollution risks.

A 1,000 cow dairy operation hauls about 12 million gallons of manure a year, and may need well over 2 thousand acres of land for safe manure disposal. Manure is expensive to haul, so there may be a tendency to apply too much manure on nearby fields. That increases water pollution risks.

Photo: UW-Extension (Discovery Farms)

Managing Nutrients

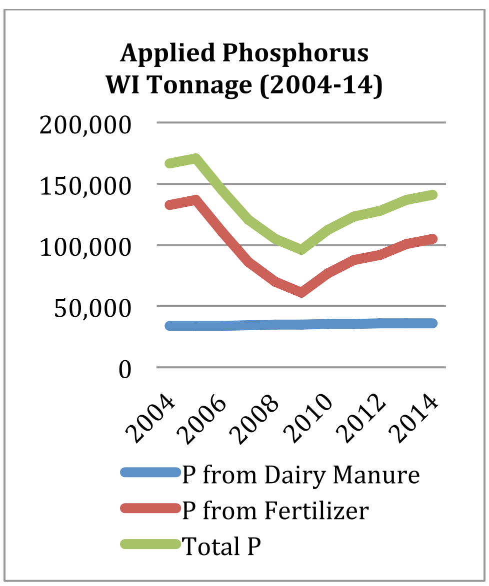
Although dairy manure is a big source of nitrogen and phosphorus in some parts of the state,[229] imported commercial fertilizer is a much bigger statewide source.[230] In 2014, dairy manure supplied roughly 209 thousand tons of nitrogen[231] and 36 thousand tons of phosphorus to Wisconsin farms,[232] while imported fertilizer provided up to 367 thousand tons of nitrogen and 105 thousand tons of phosphorus.[233] Although imported commercial fertilizer supports Wisconsin crop production, a portion of the imported nutrients will end up polluting Wisconsin lakes and groundwater.



In 2014, dairy manure supplied about 209 thousand tons of nitrogen to Wisconsin cropland, while imported commercial fertilizer supplied up to 367 thousand tons.

Chart: Nitrogen from manure was estimated by multiplying total annual manure production by the average weight of nitrogen per lb. of manure (derived from ASABE).[234] Fertilizer tonnage was obtained from DATCP annual fertilizer tonnage reports (less than 5% non-agricultural tonnage).

Both manure and commercial fertilizer carry water pollution risks. Manure tends to be over-applied near production locations, because it is expensive to haul and store. Surface applications, particularly in winter, can also pose direct runoff risks. Commercial fertilizer is more convenient, and can be applied more precisely, but its chemical form makes it susceptible to rapid leaching and runoff. Some of the nutrients in manure are released more gradually, because they are tied to organic matter.



In 2014, dairy manure supplied about 36 thousand tons of phosphorus to Wisconsin cropland, while commercial fertilizer provided up to 105 thousand tons.

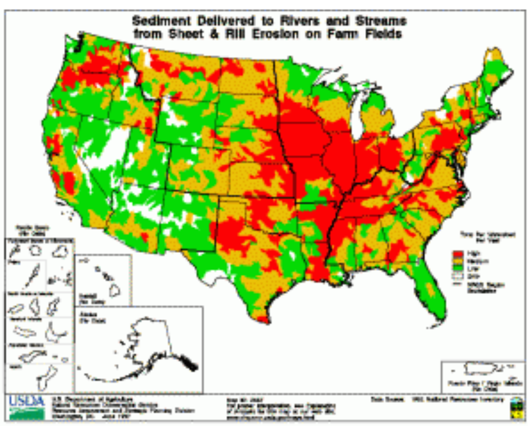
Chart: Phosphorus from manure was estimated by multiplying total annual manure production by the average weight of phosphorus per lb. of manure (derived from ASABE).[235] Fertilizer tonnage was obtained from DATCP annual fertilizer tonnage reports (less than 5% non-agricultural tonnage)

In order to minimize pollution risks, today's farmers need sound nutrient management plans.[236] It is important for farmers to test their soils, calculate reasonable nutrient needs based on cropping plans, determine the amount of land required for safe manure disposal, and credit nutrient contributions from all sources – including, but not limited to, manure and fertilizer.[237] Without careful planning, operators can easily apply too much manure and fertilizer. They can also pay for nutrients that they don't really need. Only about 30% of Wisconsin farms have written nutrient management plans at this time.[238]

Soil Erosion and Nonpoint Pollution

During the 1930's "Dust Bowl" era, President Franklin D. Roosevelt famously warned that "A nation that destroys its soils, destroys itself."[239] But soil erosion continues to undermine our agricultural land base, and is a major emerging threat to global food production.[240] The U.S. soil erosion problem centers on the Upper Midwest Farm Belt, one of the most important soil resources on the planet.

The U.S. soil erosion rate, while lower than that of many countries, is still far above the rate at which soil can be naturally replenished.[241] By some estimates, the U.S. may be losing an average of one inch of topsoil every 35 years.[242] A third of our native topsoil may already be gone.[243]



By some estimates, the U.S. may be losing an inch of topsoil every 35 years. A third of our native topsoil may already be gone. Erosion is especially severe in the Upper Midwest Farm Belt, one of the world's most important soil resources.

Erosion Map: USDA

Soil erosion from farms is perhaps the largest water pollution delivery system in the U.S.[244] Of the billions of tons of soil lost from U.S. farms each year, up to 60% may end up in surface waters.[245] Along with the sediment comes pollution from fertilizer, pesticides and manure. Farm runoff from the Upper Midwest is largely responsible for a vast "dead zone" in the Gulf of Mexico,[246] now the size of Connecticut.[247]

Closer to home, farm runoff is also contributing to a "dead zone" in Green Bay – the scenic arm of Lake Michigan where Europeans first encountered Wisconsin's native people in 1634.[248] Hundreds of other Wisconsin lakes and streams have been designated as "impaired waters" because of high phosphorus and sediment loads caused by soil erosion.[249]

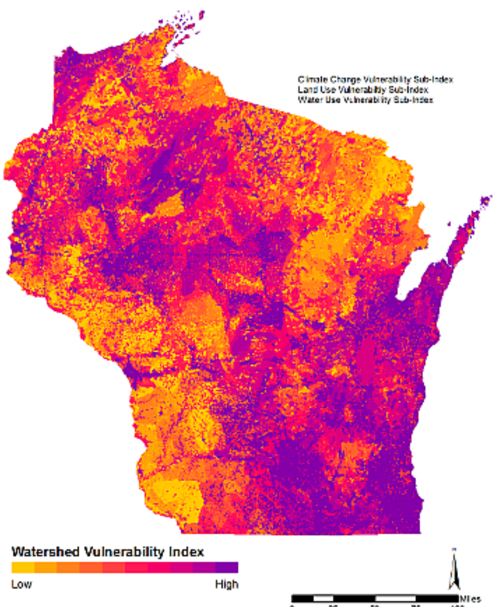
Phosphorus plays a decisive role in the algae blooms that choke many of our lakes. The algae blooms hinder enjoyment of the lakes, and can sometimes be toxic to humans and pets. In 2014, a large toxic algae bloom in Lake Erie shut down the entire municipal drinking water supply for Toledo, Ohio.[250] Like Toledo, several Wisconsin cities (including Milwaukee) get their drinking water from Great Lakes surface waters.

> *Soil erosion is the primary vehicle by which phosphorus moves from farms to lakes. Phosphorus loading causes lake eutrophication and potentially toxic algae blooms.*

In 2014, a toxic Lake Erie algae bloom shut down the entire municipal water supply of Toledo, Ohio.

Satellite photo: NOAA

The Wisconsin DNR and U.S. EPA have done a vulnerability assessment of Wisconsin watersheds based on emerging climate, land use, population and water use trends.[251] The following map shows where soil erosion and nonpoint pollution may have the biggest adverse impact on Wisconsin residents in the years ahead:



> *Wisconsin soil erosion rates are now higher than at any time since the 1980's, mainly due to cropping changes and more extreme weather events. Climate change modeling suggests that, without strong preventive action, erosion rates could double by 2050.*

Soil Erosion Projection: High Impact Areas

Map: Wisconsin DNR and U.S. EPA

Although the U.S. made significant progress on erosion control after the 1930's "Dustbowl" era, much of that progress now hangs in the balance. Wisconsin soil erosion rates are now higher than at any time since the 1980's, mainly due to cropping changes and more extreme weather events.[252] Climate change modeling suggests that Wisconsin soil erosion rates could double by 2050 without stronger preventive action.[253]

Powerful economic forces have undermined erosion control efforts. In response to high crop prices over the last decade, U.S. farmers have shifted millions of acres *out of* pasture and perennial grass, and *into* corn and other row crops that are more susceptible to erosion (Wisconsin is no exception). Since 2008, U.S. farmers have shifted more than 5 million acres out of the federal Conservation Reserve Program alone.[254] The heavy shift to cash grain monoculture has also reduced crop rotation strategies that limit erosion.

Agriculture and the Native Environment

Agriculture, by its very nature, converts complex native ecosystems to narrower human-centered uses. Wisconsin agriculture has developed, over many years, by converting native prairie, woodland and wetland ecosystems to human food production. The land now supports *many* more people, but at a cost. Many beautiful and important things have been lost.

Agriculture, by its very nature, converts complex native ecosystems to narrower human-centered uses. The U.S. has converted nearly 100% of its native prairie to agriculture and development. Much of our original prairie soil – some of the best soil in the world – has already been lost to erosion.

Native prairie.
Image: Wis. Dept. of Natural Resources

Native prairies were especially important in building and retaining the fertile topsoil on which U.S. agriculture now depends. Prairies were home to a diverse community of plants and animals, including native pollinators, and sequestered huge amounts of carbon in their deep root systems.

In the 19th and 20th centuries, the U.S. (including Wisconsin) converted nearly 100% of its native prairie to agricultural and other uses. From a greenhouse gas perspective, that was tantamount to cutting down the entire Amazon rainforest.[255] In the years that have followed, much of the native prairie soil – perhaps the most important soil resource on the planet – has been blown or washed away.

Finding a Way Forward

In 1851, the brash young State of Wisconsin adopted a one-word motto: *"Forward."*[256] On its face, the motto seems to contemplate a direct, pre-ordained march toward a Manifest Destiny. But a deeper reading – more suited to the complex world in which we now find ourselves – begins with a question: *"Which way forward?"* In a democratic society, this reading commits us to an ongoing quest, and a solemn social compact. It says that here, in Wisconsin, we will work *together* – as free, respectful, and *responsible* citizens – to find and follow a wise path toward our shared future.

Which Way Forward?

Raising the "Wisconsin" Statue to the Capitol Dome: A Daunting Shared Task

Image: Wisconsin Historical Society
Raising "Wisconsin" Statue (Image 9566)
Used by Permission

As we look forward together, we might ask ourselves the following questions:

- What makes Wisconsin a good place to live, work and raise our children?
- What things about our state do we cherish most deeply?
- How important are food, land and water?
- What is our vision for the future of Wisconsin food, land and water?
- Are we moving toward our vision, or away from it? Where does our current path lead?
- Can we realize our vision? If so, how? What will it take?
- What legacy will we leave to future generations?
- What does "Wisconsin" stand for? What image and values do we want to project as a state, a community, an industry, a business, a landowner or a citizen?
- How do our personal or business choices affect others? How do they affect our shared future?
- What can *I* do? What can *we* do?
- How can we work *together* to make Wisconsin a shining example for generations to come?

How can we work TOGETHER to make Wisconsin a shining example for generations to come?

"Wisconsin" atop the Capitol Dome.

Photo Courtesy of Richard A. Hurd
(via Wikimedia Commons)

March 28, 2016

NOTES

The author thanks all the friends who commented on earlier drafts. He would especially like to thank Ed Odgers, retired chief agricultural engineer for the Wisconsin Department of Agriculture, Trade and Consumer Protection, who provided information and analysis related to the complex topic of dairy manure (among other things). The author is solely responsible for any errors or shortcomings in the final product.

---

[1] *See* Egan-Robinson, "Wisconsin's Population: The State, Its Counties and Municipalities, 2010-2040," UW-Madison Applied Population Laboratory, Prepared for the Wis. Dept. of Administration, Demographic Services Center (December 2013).
[2] Based on U.S. Department of Agriculture (USDA) statistics related to average U.S. per capita food consumption. *See* USDA *Agriculture Factbook* (2001-02), Chapter 2, "Profiling Food Consumption in America."
[3] Based on statement related to major U.S. cities by Tom McGinn DVM, U.S. Department of Homeland Security, before the House Committee on Homeland Security, Subcommittee on Management, Investigations and Oversight, July 9, 2007.
[4] USDA *Agriculture Factbook* (2001-02), Chapter 2, *supra.*
[5] *Ibid.*
[6] *Ibid*.
[7] Buzby et al., "The Estimated Amount, Value, and Calories of Post-Harvest Food Losses at the Retail and Consumer Levels in the United States," USDA-Economic Research Service (USDA-ERS), Economic Information Bulletin No. EIB-121 (February, 2014). Estimating waste by weight has its shortcomings, because it may include things like cooking loss. Even so, the waste is considerable.
[8] *Ibid.*
[9] U.S. Environmental Protection Agency (EPA) estimate, cited in Craven-McGinty "The Challenge in Taking a Bite Out of Food Waste," Wall St. Journal, August 29, 2015.
[10] Coleman-Jensen et al., "Food Security in the United States in 2013," USDA-ERS Economic Research Report No. ERR-173 (September 2014).
[11] "Food Retailers, Agriculture Industry, and Charitable Organizations Support First National Goal to Reduce Food Waste by 50 Percent by 2030," USDA news release (September 16, 2015).
[12] Wisconsin Milk Marketing Board staff estimate, cerca 2008.
[13] USDA-ERS website at Home/Topics/In the News/California Drought: Farm and Food Impacts/California Drought: Crop Sector. *Compare* USDA-National Agricultural Statistics Services (USDA-NASS), "Vegetables, 2014 Summary" (January 2015); USDA-NASS, "California Agricultural Statistics" (2013). California accounted for over half of all U.S. fresh vegetable *production* in 2014, but not all of that production is *consumed* in the U.S.
[14] USDA-ERS website at Home/Topics/International Markets and Trade/ U.S. Agricultural Trade (January 2015). See downloadable table of U.S. agricultural trade by calendar year.
[15] *Ibid*, at "Import Share of Consumption."
[16] *See* U.S. Food and Drug Administration (FDA) news release (April 23, 2012); National Oceanic and Atmospheric Administration (NOAA) *FishWatch* website at *http://www.fishwatch.gov/sustainable-seafood/the-global-picture* (last visited January 2016). *See* also Promod et al., "Estimates of Illegal and Unreported Fish in Seafood Imports to the USA," *Journal of Marine Policy*, Vol. 48 (September 2014) at 102-113, which estimates that 20-32% of wild seafood imported to the U.S. is illegally caught.
[17] Gale and Huang, "Chinese Apple Juice Export Growth Follows Investments in the Industry," USDA-ERS *Amber Waves* Magazine (March 14, 2011).
[18] FDA import registration statistics, 2014. Registration numbers are down from the years prior to 2011 because many (possibly inactive) registrants failed to renew their import registrations when required to do so under the federal Food Safety Modernization Act (signed January 4, 2011).
[19] "Globalization in Every Loaf," *New York Times* (June 16, 2007). See also *Food Safety News*, June 3, 2012.
[20] USDA-ERS website at Home/Topics/International Markets & Trade/U.S. Agricultural Trade/Export Share of Production (visited January, 2014).

[21] *See* USDA-ERS website chart at http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/agricultural-trade.aspx ("Export Share of U.S. Farm Production, 2009-11," last updated April, 2014). The 20% corn export share (higher than the apparent percentage shown on the chart) is based on corn statistics at http://www.ers.usda.gov/topics/crops/corn/background.aspx (January, 2015). The milk export share is based on total milk solids, including those in manufactured dairy products. *See* U.S. Dairy Export Council, export trade data at http://www.usdec.org.

[22] Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) news release (February 12, 2015). See also USDA – Economic Research Service (USDA-ERS) website, at Home/Topics/International Markets and Trade/U.S. Agricultural Trade, for downloadable table of U.S. agricultural trade by calendar year.

[23] DATCP news release (February 12, 2015).

[24] *Ibid.*

[25] DATCP news release (February 19, 2014).

[26] *See* Newman, "Weak Crop Prices Hit Farm Incomes," *Wall Street Journal* (November 25, 2015). According USDA-National Agricultural Statistics Service (USDA-NASS), U.S. farmers produced about 10.76 billion bushels of corn in 2012 (down from the preceding year, partly because of drought). When world corn prices rose in response to short supplies, U.S. farmers increased corn acreage and production – producing 13.99 billion bushels in 2013, 14.22 billion bushels in 2014, and 13.59 bushels in 2015 (September 11, 2015 estimate). Average annual U.S. corn production over the 2013-15 period was nearly *30% higher* than in 2012 (27% higher than 2011). The U.S. now produces *5 times more corn per year* than in it did in1954, when it produced about 2.71 billion bushels. See production trend table at National Corngrowers Association, *World of Corn* website, http://www.worldofcorn.com/#us-corn-production (visited January, 2016).

[27] Compare U.S. Census Bureau estimates of Wisconsin, U.S. and world populations for 1915 and 2015.

[28] United Nations, *World Population Prospects: The 2012 Revision* (2013).

[29] United Nations, Food and Agricultural Organization (FAO) statistics.

[30] "Thirsty Exports," *National Geographic* (May, 2015), citing other sources.

[31] United Nations (FAO) projection cited in National Academy of Sciences, "The Critical Role of Animal Science Research in Food Security and Sustainability" (2015), at 1.

[32] See, e.g., Southgate et al., *The World Food Economy* (2007), at 221.

[33] *See* USDA-ERS website background summaries for corn and soybeans at http://www.ers.usda.gov/topics/crops/corn/background.aspx (last updated October 16, 2014) and http://www.ers.usda.gov/topics/crops/soybeans-oil-crops/background.aspx (last updated October, 2012). In 2013, the U.S. corn crop had a farm value of $61.68 billion (compared to $43.65 billion for soybeans, $14.67 billion for wheat, $1.68 billion for sorghum, and $1.32 billion for barley). *See* National Corn Growers Association, *World of Corn* website at http://www.worldofcorn.com/#us-select-crop-value (January 2016).

[34] USDA statistics. Soybeans are normally crushed to produce meal and oil. Almost all of the meal is used for livestock feed (the oil has various uses, including food and feed uses). Over half of our total corn crop, including nearly all of our exported corn, goes for feed. Feed uses account for a smaller share of domestically used corn, because a large share of our domestically used corn goes for ethanol production.

[35] According to USDA-ERS, ethanol production accounted for 44% of U.S. *domestic* corn use in 2014. *See* http://www.ers.usda.gov/media/866543/cornusetable.html. That probably overstates ethanol's share of the *total* U.S. corn crop, because it does *not* account for U.S. corn that is exported for feed (up to 20% of the total U.S. crop); nor does it account for ethanol production byproducts, known as distiller's grains or DDGs, that are used for feed. DDGs represent about 30% by weight of the corn used in ethanol production process. According to statistics published by the National Corngrowers Association, it appears that the 2014 corn crop was used roughly as follows: 60% feed, including domestic feed corn, DDGs (most used for feed), and exported corn (most used for feed); 31% ethanol (net of DDGs); and 9% food and other uses (mainly corn oil and sweeteners). *See* National Corngrowers Association, *World of Corn (2015)* at http://www.ncga.com/upload/files/documents/pdf/publications/WOC-2015.pdf.

[36] *See* National Corngrowers Association, *World of Corn (2015)* at http://www.ncga.com/upload/files/documents/pdf/publications/WOC-2015.pdf.

[37] For a chart showing corn acreage trends, see USDA-NASS website (January 2015) at Home/Charts and Maps/Field Crops, "Corn Acreage by Year, U.S." *See also* the acreage trend chart on the National Corngrowers Association website, *The World of Corn* at http://www.ncga.com/worldofcorn.

[38] A recent University of Wisconsin-Madison study suggests that, between 2008 and 2012, about 5.7 million acres of U.S. grassland were converted to crop production (most to corn and soybeans). Lark et al., "Cropland Expansion Outpaces Agricultural and Biofuel Policies in the United States," *Environmental Research Letters*, 10-4 (April 2, 2015).

[39] USDA-NASS statistics. *See also* the National Corngrowers Association, "Corn Usage By Segment," *World of Corn (2015)* at http://www.worldofcorn.com/#corn-usage-by-segment. Corn statistics refer to "field corn," which represents the overwhelming majority of all corn grown in the U.S. "Sweet corn" is a much smaller specialty crop grown for direct human consumption in fresh, canned or frozen form. In 2014, according to USDA statistics, U.S. farmers planted 90.6 *million* acres of "field corn" and only 555 *thousand* acres of "sweet corn" (includes "sweet corn" for fresh market *and* processing) – a ratio of over 163 acres of "field corn" to every acre of "sweet corn." Wisconsin is a leading "sweet corn" state, and an important "field corn" state.

[40] Gallo, "Food Advertising in the United States," chapter 9 of *America's Eating Habits; Changes and Consequences*, United States Department of Agriculture, Economic Research Service, Agriculture Information Bulletin No. (AIB750), May 1999, at p. 142 (Figure 4).

[41] See, e.g., "Sugary Drinks and Obesity Fact Sheet," Harvard School of Public Health, available at http://www.hsph.harvard.edu/nutritionsource/sugary-drinks-fact-sheet/ (last visited November 2015); Sifferlin, "This Is the No. 1 Driver of Diabetes and Obesity," *Time* (January 29, 2015), citing DiNicolantonio et al., "A Principle Driver of Type 2 Diabetes Mellitus and Its Consequences, *Mayo Clinic Proceedings* (March 2015); and Corliss, "Eating too much sugar increases the risk of dying with heart disease," Harvard Health Publications, Harvard Medical School (February 6, 2014), citing Yang et al., "Added Sugar Intake and Cardiovascular Diseases Mortality Among U.S. Adults, *JAMA Internal Medicine* (April 2014).

[42] *See, e.g.,* Southgate et al., *supra* at 33-34; Deepak K. Ray et al., *Yield Trends Are Insufficient to Double Global Crop Production by 2050,* PLoS ONE 8-6 (online journal, June 19, 2013). Some federal officials have projected even higher production requirements. For example, in a speech to The Atlantic's Food Summit, on April 26, 2011, USDA Deputy Secretary Kathleen Merrigan spoke of the need to increase world food production by *70%* by mid-century.

[43] See University of Washington chart illustrating, for various countries, the estimated share of annual income spent on food: http://wsm.wsu.edu/researcher/wsmaug11_billions.pdf.

[44] USDA, *1960 Yearbook of Agriculture*, at p. 4.

[45] U.S. Department of Energy (2014). The U.S. percentage has declined in recent years, as China and other countries have increased their usage.

[46] Canning et al., "Energy Use in the U.S. Food System," USDA Economic Research Service, ERR-94 (March 2010). The study results are generally consistent with those cited in note 48, *infra*. *See also* Smil, *Energy at the Crossroads* (MIT Press 2005), at 54. According to Canning, et al., over 80% of the *increase* in total annual U.S. energy use between 1997 and 2002 was food-related. About half of that was due to population growth and higher food consumption, and half to energy intensification. Commercial food processing was a major growth area, as households "out-sourced" more food preparation to commercial processors (possibly limiting some energy use in home kitchens).

[47] According to the U.S. Department of Energy, more than 82% of all U.S. energy comes from fossil fuel (the rest comes from nuclear, solar, hydro and biofuel sources). *See* "U.S. Sources and Uses of Energy," U.S. Department of Energy (2013). Food sector energy source patterns are, presumably, comparable to other sectors of the economy.

[48] Hendrickson, "Energy Use in the U.S. Food System: A Summary of Existing Research and Analysis," University of Wisconsin Center for Integrated Agricultural Systems (2004); Heller and Keoleian, "Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System," Report No. CSS00-04, Center for Sustainable Systems, University of Michigan (2000). Most electrical energy is currently derived from generating facilities powered by fossil fuel.

[49] Canning, et al., *supra.*
[50] *Ibid.*
[51] *Ibid.*
[52] Greenhouse gases include carbon dioxide, methane and nitrous oxide, among others. Carbon dioxide accounts for 82% of all greenhouse gases generated by human activity in the U.S. *See* U.S. EPA, "U.S. Greenhouse Gas Inventory Report: 1990-2013," at http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (October 5, 2015).
[53] *See* World Bank statistics for 2011. China produces more total greenhouse gas than the U.S.; but on a per capita basis, the U.S. produces nearly 3 times more than China. *See* Ge et al., "6 Graphs Explain the World's Top Emitters," World Resources Institute (November 25, 2014).
[54] This estimate assumes that the 16% food system share of total U.S. energy use is allocated among energy sources (electricity, natural gas, motor fuel, etc.) in approximately the same proportions as the other 84% of U.S. energy use. It is somewhat difficult to isolate food system shares of U.S. energy use and carbon dioxide emissions, because they are often subsumed in other common energy use categories such as transportation or electrical generation.
[55] Carbon dioxide accounts for 82% of all U.S. greenhouse gas emissions. *See* "U.S. Greenhouse Gas Inventory Report 1990-2013," note 52 *supra.* If the food system accounts for 16% of U.S. carbon dioxide emissions, it follows that those carbon dioxide emissions represent 13% of all U.S. greenhouse gas emissions.
[56] U.S. EPA, "Sources of Greenhouse Gas Emissions" (Agricultural Sector Emissions)," at http://www3.epa.gov/climatechange/ghgemissions/sources/agriculture.html (October 5, 2015).
[57] About 10 years ago, major petroleum companies began using ethanol as an environmentally-friendly substitute for MTBE, an octane-enhancing gasoline additive that was found to be a serious water pollutant. Federal ethanol blending mandates and subsidies subsequently expanded the use of ethanol as a motor fuel – not just an octane-enhancing gasoline additive. The U.S. currently produces about 14 billion gallons of ethanol per year (U.S. Energy Information Administration, 2014).
[58] Harder and Newman, "U.S. Quotas Give Boost to Ethanol Producers," *Wall Street Journal* (December 1, 2015). Although ethanol subsidies have now expired, the blending mandate continues. On November 30, 2015, EPA reduced the blending mandate, but not by as much as originally proposed.
[59] This energy balance estimate is a nationwide average figure (ethanol production efficiency varies by region and production facility). *See* Gallagher, et al., "2015 Energy Balance for the Corn-Ethanol Industry" (February, 2016). This study was sponsored by USDA, Office of the Chief Economist, Office of Energy Policy and New Uses, and is available at http://www.usda.gov/oce/reports/energy/2015EnergyBalanceCornEthanol.pdf. *Compare* an earlier USDA study by Shapouri et al., "The Energy Balance of Corn Ethanol: An Update," USDA-ERS Agricultural Economic Report #813 (2002), which suggested a less favorable energy balance. Much of the fossil energy used in corn production and processing comes from non-petroleum fossil fuel sources, such as natural gas.
[60] Deller, "Contribution of Agriculture to the Wisconsin Economy," University of Wisconsin-Extension (September, 2014).
[61] *Ibid.*
[62] Wisconsin Milk Marketing Board, based on USDA-NASS statistics.
[63] Memo from Prof. Steven Deller, University of Wisconsin-Extension, to Jeff Swenson, DATCP (March 19, 2007).
[64] USDA-NASS statistics.
[65] USDA-ERS, "Trends in Local and Regional Food Systems: A Report to Congress" (January 2015), p. 5 (Table 2), showing figures for 2002-2012. "Local food" is hard to define: it includes, but is not necessarily limited to, food that farmers market directly to local consumers. According to USDA, only about 7% of farms do any direct marketing to consumers. Farms with less than $75,000 in annual gross farm income accounted for 85% of "local food" farms in 2012, but accounted for only 13% of "local food" sales. Farms with more than $350,000 in annual gross farm income accounted for only 5% of "local food farms" in 2012, but accounted for 67% of "local food" sales (see report summary).

[66] *See* American Farmland Trust, Farmland Information Center at www.farmlandinfo.org/.

[67] USDA-ERS (1929-present) and U.S. Bureau of Labor Statistics (1901-present).
[68] DeHoyos and Lessen, *Food Shares in Consumption: New Evidence Using Engel Curves,* World Bank (2008), p. 5.
[69] Food Marketing Institute, "Supermarket Facts" (2016), citing statistics from 2014.
[70] U.S. Government Accounting Office (GAO), *Agricultural Concentration and Agricultural Commodity and Retail Food Prices,* GAO-09-746R (2009); Food and Water Watch, Iowa Farmers Union, Missouri Rural Crisis Center, National Farmers Union, "The Anticompetitive Effects of the Proposed JBS-Cargill Pork Packing Acquisition" (July 2015). According to the latter study, if the proposed JBS-Cargill acquisition deal is approved, the percentage of hogs slaughtered by the top 4 firms would increase to over 75%.
[71] Smithfield alone slaughters about 27% of all U.S. hogs. Food and Water Watch, Iowa Farmers Union, Missouri Rural Crisis Center, National Farmers Union, "The Anticompetitive Effects of the Proposed JBS-Cargill Pork Packing Acquisition" (July 2015).
[72] *Ibid.*
[73] USDA, Grain Inspection, Packers and Stockyards Administration (GIPSA), *Packers and Stockyards Statistical Report, 2006 Reporting Year* (published in 2008).
[74] Smithfield Annual Report (2009) and Duke University Report on *North Carolina and the Global Economy* (2010).
[75] Key and McBride, *The Changing Economics of U.S. Hog Production*, USDA Economic Research Report No. 52 (2007), cited in Wise and Trist, "Buyer Power in U.S. Hog Markets: A Critical Review of the Literature," Tufts University, Global Development and Environment Institute Working Paper No. 10-04 (2010) at p. 6.
[76] USDA Secretary Vilsack, *USDA/DOJ Workshop on Agriculture and Antitrust Enforcement Issues* (December 8, 2010) pdf transcript at p. 41.
[77] At least one very large hog operation is now planning to locate in the Bayfield, WI area, near Lake Superior, in order to escape a new swine disease (porcine epidemic diarrheal virus, or PEDv) that recently killed up to 10% of the pigs (mainly piglets) in states where hog operations are now heavily concentrated. The Bayfield siting controversy is described in Bergquist, "Proposed hog megafarm causes a stir in Bayfield County, *Milwaukee Journal-Sentinel* (June 27, 2015). The disease outbreak is described in "Virus Kills Millions of American Pigs, Pushing Up Pork Prices," *National Geographic*, May 1, 2014.
[78] USDA-ERS, "Structure and Size of U.S. Farms" (2010).
[79] USDA-ERS, "Farm Household Income" (2014). The group medium income of farms selling less than $350,000 per year is negative, which is to say that more than half of the farms in that group are operating at a loss.
[80] *Ibid.*
[81] USDA-NASS Census of Agriculture (2012). See Census Highlights, "Farm Demographics."
[82] Nesbit, *The History of Wisconsin Volume III, Urbanization and Industrialization 1873-1893* (State Historical Society of Wisconsin,1985), p. 1.
[83] Wisconsin Bluebook, 2003-04, p. 109 (chart).
[84] *Ibid*, p. 109.
[85] USDA-NASS statistics.
[86] In 2012, Wisconsin had over 22 thousand prisoners in state prisons alone (this does not include county jail inmates, federal prisoners, or offenders supervised in the community). Wisconsin Legislative Fiscal Bureau, Information Paper 56, January 2013.
[87] USDA Census of Agriculture, 2007. Many large Wisconsin dairy farms (as well as meat and food processing plants) now rely heavily on immigrant labor.
[88] USDA statistics, 2012.
[89] *See* USDA-ERS, "Trends in Local and Regional Food Systems: A Report to Congress" (January 2015), According to USDA, direct farm-to-consumer sales represent only 0.4% of all agricultural sales. Only about 7% of farms do any direct marketing to consumers. Farms with less than $75,000 in annual gross farm income accounted for 85% of "local food farms" in 2012, but accounted for only 13% of "local food" sales. Farms with more than $350,000 in annual gross farm income accounted for only 5% of "local food" farms in 2012, but accounted for 67% of "local food" sales.

[90] USDA-ERS, "Retail Trends" at http://www.ers.usda.gov/topics/food-markets-prices/retailing-wholesaling/retail-trends.aspx. *Compare* Agricultural Marketing Resource Center, "Grocery Industry" (February, 2010). Wal-Mart, one of the world's biggest companies, now controls over 20% of the U.S. grocery market.
[91] Nation's Restaurant News (December 19, 2005).
[92] Matson, Tang and Wynn, "Seeds, Patents and Power: The Shifting Foundation of Our Food System" (November 1, 2014) at 25, citing other sources. Paper may be downloaded, free of charge, from the Social Science Research Network (SSRN) at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2525120.
[93] *Ibid*, at 25-27.
[94] *Ibid*, at 25-27.
[95] *Ibid*, at 24.
[96] James Owen, "Farming Claims Almost Half Earth's Land, New Maps Show," *National Geographic News* (December 9, 2005), citing research by the University of Wisconsin-Madison, Center for Sustainability and the Global Environment.
[97] United Nations, Food and Agriculture Organization (FAO) statistics. See FAO graph reproduced in this document.
[98] "The 2010 NRI: Changes in Land Cover/Use," American Farmland Trust. Based on USDA National Resources Inventory (NRI).
[99] American Farmland Trust, Farmland Information Center (2015), at http://www.farmlandinfo.org.
[100] *Ibid.*
[101] *Ibid.*
[102] *Ibid*.
[103] Compare current and past county farmland preservation plans certified under Wisconsin's farmland preservation program (Wis. Stats. Ch. 91, administered by DATCP).
[104] USDA-ERS, "Irrigation and Water Use" (updated 2013).
[105] Based on cash farm receipts. USDA-NASS, "California Farm Receipts Reach New High in 2010," *California Farm News* (2010).
[106] Krieger, "California Drought: San Joaquin Valley sinking as farmers race to tap aquifer," San Jose Mercury News (March 29,2014).
[107] Almond Board of California, *2013 Almond Almanac*, available at http://www.almonds.com/sites/default/files/content/attachments/2013_almanac.pdf.
[108] *Ibid.*
[109] Davidow and Malone, "How 'Virtual' Water Can Help Ease California's Drought," *Wall Street Journal* (March 21, 2015).
[110] *Ibid.*
[111] Almond Board of California, *supra.*
[112] Davidow and Malone, *supra.*
[113] McNeill, *Something New Under the Sun: An Environmental History of the 20th Century World* (Norton paperback edition, 2001), at 151.
[114] *Ibid*, at 154.
[115] Wisconsin Department of Natural Resources (DNR) statistics, cited in "Big farms, frac mines could feel force of judge's groundwater ruling," *The Cap Times* (Madison, WI, September 20, 2014).
[116] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015); Wisconsin Initiative on Climate Change Impacts, *Central Sands Hydrology Working Group Report* (2011).
[117] *See*, for example, Lesk, "Hull residents want $233K from city over well," *Stevens Point Journal* (September 16, 2015).
[118] *See* Flescher, "With Shrinking Aquifer in Poor Shape, Waukesha Yearns for Lake Michigan Water," *Wisconsin State Journal* (October 9, 2013). On January 7, 2016, the Wisconsin DNR forwarded Waukesha's diversion application to the other Great Lakes states and the Canadian provinces of Ontario and Quebec. Before the City of Waukesha can begin a diversion, all eight Great Lakes states and provinces must approve the application.
[119] *Ibid.*

[120] According to the U.S. Geological Survey, Wisconsin Water Science Service Center, "Increased runoff from impervious surfaces causes dangerous floods, severe erosion damage to our stream channels, diminished recharge of groundwater, and degraded habitat for our fisheries. These same impervious surfaces can transport the many pollutants deposited in urban areas, such as nutrients, sediment, bacteria, pesticides, and chloride. In the worst cases, the amount of pollutants in urban runoff are high enough to prevent us from being able to swim or fish in our local waters."
[121] United States Geological Survey, computer simulation of a Pennsylvania watershed at http://pa.water.usgs.gov/reports/fs067-98.html (visited November, 2015).
[122] USDA-NASS statistics.
[123] USDA-NASS statistics. In 1950, the U.S. produced about *2.8 billion* bushels of corn on roughly 83 million harvested acres. In 2014, the U.S. produced about *14 billion* bushels of corn on about 83 million harvested acres. For charts showing production and acreage trends, see National Corn Growers website at http://www.worldofcorn.com/#/.
[124] U.S. EPA, "Agricultural Nonpoint Source Fact Sheet" EPA 841-F-05-001 (March 2005); "National Water Quality Inventory: Report to Congress; 2004 Reporting Cycle" (January 2009).
[125] DATCP, "Agricultural Chemicals in Wisconsin Groundwater" (2008).
[126] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).
[127] Wisconsin Initiative on Climate Change Impacts, *Central Sands Hydrology Working Group Report* (2011).
[128] *See*, e.g., National Research Council, *Managing Global Genetic Resources: Agricultural Crop Issues and Policies* (National Academies Press 1993). In one global study of 39 crops, researchers found that the abundance of pollinator bees was on average 76% higher in "diversified" fields than in monoculture fields. Kennedy et al., "A global quantified synthesis of local and landscape effects on wild bee pollinators in agroecosystems," *Ecology letters* 16.5 (2013), 584-599.
[129] *See*, e.g., National Research Council, *Impact of Genetically Engineered Crops on Farm Sustainability in the U.S.* (National Academies Press 2010).
[130] Smil, "Detonator of the Population Explosion," *Nature* (Vol. 400, July 29, 1999). Nitrogen fertilizer is synthesized from atmospheric nitrogen, using large amounts of fossil fuel (typically natural gas).
[131] *Ibid.*
[132] *See* USDA-ERS, "Fertilizer Use and Markets," at http://www.ers.usda.gov/topics/farm-practices-management/chemical-inputs/fertilizer-use-markets.aspx (last visited January, 2016). Nitrogen fertilizer sales increased from 2.7 million tons in 1960 to 12.8 million tons in 2011. Sales growth continued in 2012 and 2013 (see the Fertilizer Institute trend data at https://www.tfi.org/statistics/fertilizer-use (last visited January 2016).
[133] According to one study, only about 37% of the fertilizer nitrogen applied to corn is taken up by crop roots. Cassman et al., "Agro-Systems, Nitrogen Use Efficiency, and Nitrogen Management," University of Nebraska–Lincoln, Department of Agronomy and Horticulture Faculty Publications, *DigitalCommons@University of Nebraska-Lincoln*, available at http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1356&context=agronomyfacpub (last visited January, 2016). The fate of the "unused" nitrogen is complex, but a significant share finds its way to air (partly as nitrous oxide) and to water (as nitrate).
[134] *See* U.S. EPA, "Sources of Greenhouse Gas Emissions" (Agricultural Sector Emissions)," at http://www3.epa.gov/climatechange/ghgemissions/sources/agriculture.html (last accessed October 5, 2015).
[135] *See* Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).
[136] Based on DATCP annual fertilizer tonnage reports, showing statewide sales of commercial fertilizer. The reports include separate breakdowns of N and P tonnage. N applications are now at historically high levels. P applications declined from 2004-2009; but since 2009 they have rebounded to typical pre-2004 levels.
[137] USDA-NASS annual reports of Wisconsin corn acres planted.

[138] *See* University of Wisconsin nutrient management information and recommendations at http://ipcm.wisc.edu/downloads/nutrient-managment/ (last accessed November 2015). Wisconsin has adopted nutrient management planning requirements for farms (based, in part, on UW agronomic recommendations); however, compliance obligations are normally contingent on cost-sharing. *See* Wisconsin Administrative Code ch. ATCP 50. Only about 30% of Wisconsin farms actually have written nutrient management plans. *See* DATCP, "Wisconsin Making Inroads in Managing Manure," DATCP News Release (April 14, 2015).

[139] *See*, e.g., University of Wisconsin recommendations for economically optimal nitrogen applications to corn at http://ipcm.wisc.edu/download/pubsNM/NitrogenGuidelinesConrWisconsinMRTN.pdf (last accessed November 2015).

[140] *See* higher UW nitrogen recommendations for corn on sandy irrigated soils, compared to other soils, at http://ipcm.wisc.edu/download/pubsNM/NitrogenGuidelinesConrWisconsinMRTN.pdf (last accessed November 2015).

[141] *See* Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[142] *Ibid.*

[143] *Ibid.*

[144] *Ibid.* However, some studies suggest that contamination may be stabilizing – at least in some areas. For example, a recent Dane County study suggests that the *highest* nitrate levels in that county may have decreased over the past 30 years (although base levels may be trending upward). McDonald, et al., "Characterizing the sources of groundwater nitrate in Dane County, Wisconsin," Report to the Wisconsin Department of Natural Resources, October 29, 2015. Key findings are summarized in Verburg, "Major study of contaminated water shows progress, challenges ahead." *Wisconsin State Journal* (January 17, 2016).

[145] Shaw, "Nitrogen Contamination Sources: A Look at Relative Contributions," Conference Proceedings: *Nitrate in Wisconsin's Groundwater: Strategies and Challenges* (May, 1994).

[146] *Ibid.*

[147] U.S. Geological Survey, *Nutrients in the Nation's Streams and Groundwater 1992-2004,* USGS Circular 1350 (September 2010).

[148] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[149] *Ibid.*

[150] *Ibid*

[151] *Ibid.*

[152] *Ibid.*

[153] *Ibid.*

[154] The Iowa case has highlighted the potential importance of farm drainage tiles and pipes as mechanisms for the delivery of nitrate and other pollutants to surface waters. *Board of Waterworks Trustees of the City of Des Moines v. Sac County Board of Supervisors et al*., U.S. District Court for the Northern District of Iowa, Western Division, Case No. 5:15-CV-04020.

[155] Masarik, "Nitrate in Wisconsin's Groundwater – What, Why and Where," University of Wisconsin seminar (*Wednesday Night at the Lab*, Madison, WI, January 20, 2016).

[156] Center for Watershed Science and Education (CWSE), *WI Well Water Viewer*, University of Wisconsin-Stevens Point. Available online: http://www.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx (accessed April 2015).

[157] Phosphorus tends to play a more decisive role in fresh water eutrophication and algae growth, while nitrogen may play a more decisive role in the creation of salt water "dead zones" such as the one in the Gulf of Mexico (see notes 245 and 246, *infra*).

[158] *See* Wisconsin DNR, "Reducing Phosphorus to Clean Up Lakes and Rivers" (Revised December 22, 2014).

[159] *Ibid.*

[160] *Ibid.*

[161] Under the Clean Water Act, phosphorus pollution "point sources" may need to install costly phosphorus pollution controls *OR* pay others to achieve equivalent phosphorus reductions in the same phosphorus-impaired watershed (e.g., by reducing "nonpoint" phosphorus runoff from farms). Wisconsin offers a possible alternative for some affected point sources (see Wis. Stats. ss. 283.16 and 283.84(1)(c)). The costs to affected point sources will, in any case, be significant.

[162] *See* University of Wisconsin-Madison Soil Testing Laboratories, *Wisconsin's Historical 5-Year Summary Database*. *See also* Bundy et al., "Implementing Nutrient Management Practices in Wisconsin," Presentation to the American Society of Agronomy (November 4, 2003).

[163] Wisconsin has adopted soil erosion control standards for farms, but compliance obligations are usually contingent on cost-sharing. *See* Wisconsin Administrative Code Chapter ATCP 50.

[164] Wisconsin has adopted nutrient management standards (including phosphorus management standards) for farms; but compliance obligations are usually contingent on cost-sharing. *See* Wisconsin Administrative Code Chapter ATCP 50. Only about 30% of Wisconsin farms currently have written nutrient management plans. *See* DATCP, "Wisconsin Making Inroads in Managing Manure," DATCP News Release (April 14, 2015).

[165] Pesticides and labeled uses must be registered with the U.S. EPA. Wisconsin has also adopted extensive rules related to pesticide handling and use (see Wis. Adm. Code chs. ATCP 29 and 30).

[166] Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[167] *See* Wisconsin Administrative Code ch. ATCP 30, subch. VIII.

[168] *See* Wisconsin Groundwater Coordinating Council, *Report to the Legislature* (2015).

[169] *Ibid.,* citing 2007 DATCP statistical survey of Wisconsin groundwater. Metabolites of alachlor and metolachlor (herbicides also used on corn) are now the most widely detected pesticide residues in Wisconsin drinking water wells.

[170] Monsanto originally patented "Roundup" herbicide, as well as the "Roundup-Ready" GMO seed trait.

[171] *See* Matson, Tang and Wynn, "Seeds, Patents and Power: The Shifting Foundation of Our Food System" (November 1, 2014), at 26*,* citing other sources. Paper may be downloaded, free of charge, from the Social Science Research Network (SSRN) at
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2525120.

[172] Linda Bren, "Genetic Engineering: The Future of Foods?" U.S. Food and Drug Administration, *FDA Consumer Magazine 37-6* (November-December, 2003), citing estimate by the Grocery Manufacturers of America related to GMO ingredients in processed foods. Nearly all of those GMO ingredients are from crops containing the "Roundup Ready" GMO trait.

[173] *See* Matson, Tang and Wynn, "Seeds, Patents and Power: The Shifting Foundation of Our Food System" (November 1, 2014). Paper may be downloaded, free of charge, from the Social Science Research Network (SSRN) at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2525120.

[174] *See* National Research Council, *Impact of Genetically Engineered Crops on Farm Sustainability in the U.S.* (National Academies Press 2010). Widespread use of another GMO trait, which incorporates the natural insecticide bacillus thuringiensis (Bt) into corn, soybeans and other crop plants, has likewise spurred the evolution of pests that are resistant to Bt.

[175] The livestock industry currently accounts for about 80% of all U.S. antibiotic use. Statistics for 2011, cited by Dr. David Kessler, former FDA Commissioner (NY Times Op-Ed, March 27, 2013). See also Hollis and Ahmed, "Preserving Antibiotics, Rationally," *New England Journal of Medicine* (December 26, 2013). Antibiotics are used to treat disease. In some livestock sectors (though not in the dairy industry), they are also routinely fed to livestock to promote animal growth.

[176] The introduction of genetically-engineered bovine growth hormone (rBST), used to increase milk production by dairy cows, sparked a major controversy in Wisconsin and other states (see Wis. Stats. s. 97.25).

[177] Approximate percentage increase based on USDA-NASS milk production statistics. See production trend chart at USDA-NASS, "Wisconsin Agricultural Statistics" (2014), p. 39.

[178] USDA-NASS, Wisconsin Cattle and Milk Review (February 2013), graph showing "Number of Milk Cows vs. Milk Per Cow: Wisconsin 1950-2012." See also USDA-NASS statistics (Feb. 3, 2015) at http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/mkpercow.pdf. Today's cows are bigger, consume more feed, and are bred for high milk production. Milk production per cow continues to increase steadily (some top cows can now produce at nearly 3 times the current state average).

[179] For an analysis of scale-related production costs in the dairy industry, see MacDonald et al., "Profits, Costs, and the Changing Structure of Dairy Farming," USDA-ERS Economic Research Report No. 47 (September, 2007).

[180] Bundy, "The Future of Food is Chicken," *Wall Street Journal* (December 5-6, 2015), citing data from Virginia Tech.

[181] *Ibid.*

[182] USDA-NASS statistics. California has about 1,650 dairy farms, compared to nearly 10,000 in Wisconsin.

[183] USDA-NASS statistics. Herd sizes in some western states are even larger than those in California. As of 2010, average herd sizes in selected western states were as follows: New Mexico (2,293), Arizona (1,609), Nevada (1,120) and California (1,026).

[184] Based on DNR water pollution control permits issued to CAFOs.

[185] Behrends, "Wisconsin's largest dairy started as a family farm," *Agri-View* (February 26, 2015).

[186] Per Wisconsin Dairy Business Association.

[187] Today's livestock are bred mainly for high production. That has reduced the genetic diversity of some livestock (including dairy cattle and chickens), which may increase their collective susceptibility to disease. See, e.g., Notter, "The Importance of Genetic Diversity in Livestock Populations of the Future," *Journal of Animal Science,* 77: 61-69 (1999); Muir et al., "Genome-Wide Assessment of Worldwide Chicken SNP Genetic Diversity Indicates Significant Absence of Rare Alleles in Commercial Breeds," *Proceedings of the National Academy of Sciences* (2008). With modern methods, genetic diversity can be reduced within a fairly short time period. For example, with artificial insemination, a single prize dairy bull can have over 500,000 offspring. See "A Breeder Apart: Farmers Say Goodbye to a Bull that Sired 500,000 Offspring," *Wall St. Journal* (January 14, 2015).

[188] Statistics for 2011, cited by Dr. David Kessler, former FDA Commissioner, in a *New York Times* Op-Ed article (March 27, 2013). See also Hollis and Ahmed, "Preserving Antibiotics, Rationally," *New England Journal of Medicine* (December 26, 2013).

[189] *Ibid.* It should be noted that many of the antibiotics used on livestock are different from those used on humans. *See* note 190, *infra.*

[190] "Antibiotic Resistance Threats in the United States, 2013," U.S. Department of Health and Human Services, Centers for Disease Control (2013). Some antibiotics are used to treat or prevent disease, but many are fed to promote animal growth. The CDC report says that the latter practice is unnecessary, and should be phased out. It also urges more limited use of livestock antibiotics for treatment purposes. In 2015, FDA moved to reduce agricultural use of antibiotics that are also used on humans, but *not* those used only on livestock. *See* "FDA Moves to Combat Superbugs," *The Wall Street Journal* (June 3, 2015).

[191] "Antibiotic Resistance Threats in the United States, 2013," U.S. Department of Health and Human Services, Centers for Disease Control (2013).

[192] *See* Wis. Adm. Code ch. ATCP 60. Wisconsin rules implement federal policies adopted by FDA and the National Conference on Interstate Milk Shipments (NCIMS).

[193] *Ibid*.

[194] DATCP summary statistics, based on required reports from dairy plants.

[195] *See*, generally, *The Poultry Site* at http://www.thepoultrysite.com/bird-flu/bird-flu-news.php; Fry, "What the worst bird flu outbreak in U.S. history means for farms," *Fortune* (June 25, 2015); Newton and Kuethe, "Economic Implications of the 2014-2015 Bird Flu." *farmdoc daily* (5):104, Dept. of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign (June 5, 2015).

[196] USDA, Animal and Plant Health Inspection Service (USDA-APHIS), "Epidemiologic and Other Analyses of HPAI-Affected Poultry Flocks" (June 15, 2015). *See also* Sifferlin, "Bird Flu: Everything You Want to Know About the Outbreak," *TIME* web story (May 13, 2015), citing USDA staff communication.

[197] *See* notes 195 and 196, *supra.*
[198] *See* notes 195 and 196, *supra. See also* "Economic Impact of Highly Pathogenic Avian Influenza (HPAI) on Poultry in Iowa," prepared for the Iowa Farm Bureau by Decision Innovation Solutions (August 2015).
[199] Much of the biological world is, of course, invisible to the naked eye. Bacteria and other microorganisms are everywhere – in the air, in the water, in the soil, in our bodies, and on the food we eat. Their total mass may be 5 to 25 times greater than the total mass of all animal life on earth. (*See* Postgate, *Microbes and Man*, Cambridge Univ. Press, 1992.) Microorganisms are essential for all plant and animal life, including human life. But under the right conditions, some can threaten our food supply and our health.
[200] Wisconsin Milk Marketing Board, "Wisconsin's Dairy Heritage."
[201] USDA-NASS statistics.
[202] According to USDA-NASS statistics, Wisconsin had over 2.1 million cows in 1950, compared to about 1.27 million today.
[203] Dairy farm numbers per USDA-NASS statistics.
[204] *See* Cropp, "Wisconsin Cheese Plant Capacity and Future Milk Production," University of Wisconsin – Madison (July 2007); "Rethinking Dairyland," University of Wisconsin-Madison, Dept. of Agricultural and Applied Economics, Marketing and Policy Briefing Paper #78B (September, 2002), at 2. *See also* Short, "Characteristics and Production Costs of U.S. Dairy Operations," USDA-ERS Statistical Bulletin No. 974-6 (February, 2004).
[205] *See* Brat, "Big Milk Market Goes Sour," *Wall Street Journal* (October 9, 2015).
[206] Wisconsin Milk Marketing Board, "2015 Dairy Data" (based on USDA-NASS production estimate for 2014). Percentage increase is based on USDA-NASS statistics. See production trend chart at USDA-NASS, "Wisconsin Agricultural Statistics" (2014), at 39.
[207] *See* DATCP website, "Dairy 30x20 Initiative to Grow Wisconsin Dairy," at http://datcp.wi.gov/Farms/Dairy_Farming/index.aspx.
[208] Wisconsin Milk Marketing Board staff estimates.
[209] Wisconsin Milk Marketing Board statistics for 2004-2014, based on USDA statistics. Wisconsin produced about 2.4 billion lbs. of cheese in 2004, and 2.9 billion in 2014.
[210] USDA-NASS statistics (2015).
[211] USDA-NASS statistics (2015). Wisconsin produces about *45%* of the nation's specialty cheese.
[212] Annual Wisconsin dairy manure production estimates were obtained by 2 separate methods that yielded comparable results. The *first method* used a regression equation for a typical Holstein herd (Weiss, 2004), but substituted total Wisconsin cow numbers and average milk per Wisconsin cow (USDA statistics). The calculation conservatively included lactating cows and dry cows, but *not* replacement heifers or calves (it assumed a 305 day lactation period per cow). This method estimated 2014 Wisconsin dairy manure output (feces and urine as excreted, without dilution) at 63 billion lbs. The Weiss regression formula is: Lbs. of manure/cow/day = 106 + .5[Lbs. of milk/cow/day]. See Weiss, "Factors Affecting Manure Excretion by Dairy Cows," Proceedings of the Cornell Nutrition Conference (2004), at 11-20. The *second method* used Wisconsin cow numbers (USDA statistics) and a standard per-cow manure production formula [ASABE] for lactating and dry cows. This second method, like the first, ignored manure produced by calves and replacement heifers. This method estimated 2014 Wisconsin dairy manure production (feces and urine as excreted, without dilution) at 64.5 billion lbs. (slightly higher than the 63 billion lbs. estimated by the first method). ASABE assumes that a lactating cow produces 150 lbs. of manure/day (305 days per year), and a dry cow produces 83 lbs. of manure/day (60 days per year). *See* American Society of Agricultural and Biological Engineers (ASABE), D384.2, *Manure Production and Characteristics.*
[213] The 7% increase in manure production from 2004 to 2014 was estimated using the *first method* [Weiss] described in note 212 *supra*. The second estimation method (ASABE) yields higher total manure volumes over the entire period from 2004 to 2014, but a slower rate of growth.
[214] See methodology, note 212 *supra*.
[215] See methodology, note 212 *supra*.
[216] *See*, generally, EPA website, Agriculture 101, Environment, Pathogens; Ebner, "CAFO's and Public Health: Pathogens and Manure," Purdue University Extension (2007).

[217] "While dairy farms of all sizes have the potential for substantial excess nutrient production, the potential appears to increase noticeably among larger dairy operations, particularly for phosphorus and as herd sizes exceed 1,000 cattle of all types. As dairy farming continues to consolidate into larger operations, this problem will likely become more widespread." MacDonald et al., "Profits, Costs, and the Changing Structure of Dairy Farming," USDA-ERS, *ERR 47* (September 2007), at 25.
[218] *See* Fleming and Ford, "Human versus Animals – Comparison of Waste Properties," University of Guelph, Canada (2001).
[219] A few large dairy farms do treat their manure to some degree, and at least one county (Dane) has experimented with subsidized manure treatment facilities that serve multiple farms. *Manure digesters* are used to produce bio-fuel (methane) from manure, and can help to reduce manure odor and pathogen risks; but they do *not* make manure "disappear." Additional steps are needed to extract nutrients and water, and each step adds significant cost. Treatment costs are only partially offset by the value of extracted bio-fuel, nutrients and other by-products, at today's prices. Only the very largest dairy farms are capable of financing and operating their own manure treatment systems at this time, and there are obstacles to sharing manure treatment services between farms. Public subsidies, which shift manure treatment costs to taxpayers, may tend to favor some dairy operations to the exclusion of others. They may also send the wrong "price signals" to dairy operators – encouraging them to over-expand and produce "too much" manure, because manure treatment and disposal costs are shifted to the taxpaying public. In theory, dairy farmers might be willing to pay "user fees" for treatment services that reduce their manure storage, hauling or management costs; but, for a variety of reasons (including limited implementation of nutrient management standards), private markets for such services do not yet exist. Farmer cooperatives and dairy processors, which have an important stake in the matter, could conceivably help to develop shared manure treatment business models. But current market conditions are less than favorable. *See*, for example, Kesmodel, "Bull Market Fades for Manure Power," *Wall Street Journal*, February 19, 2016.
[220] Per communication from the Wisconsin Land and Water Conservation Association.
[221] *See* U.S. Biogas LLC, "Springfield Community Digester Nutrient Concentration System Feasibility Report - Dane County" (October, 2013). According to the U.S. Biogas study, the average hauling cost is roughly $.015 per gallon (costs vary). In Dane County alone, farmers spend over $3.5 million to haul and apply manure each year. A dairy farm with 1,000 cows hauls about 11.5 million gallons of manure per year, at an average cost of roughly $173,000. Total costs increase as manure is hauled further.
[222] Per USDA-Natural Resource Conservation Service (USDA-NRCS) Technical Guide 313 (Waste Storage Facility).
[223] If a new or expanding herd will have 1,000 or more "animal units" (about 700 cows), it must obtain a state CAFO permit and meet manure storage and management standards. *See* Wis. Adm. Code ch. NR 243. No state permit is required for herds below 1,000 "animal units." However, a county, town or municipality *may* adopt a livestock facility siting ordinance that requires new or expanding facilities over 500 "animal units" (about 350 cows) to obtain a *local* permit. Permit applicants must meet state standards for manure storage and handling, nutrient management, runoff control, odor and setbacks. *See* Wis. Adm. Code ch. ATCP 51. For a map showing local jurisdictions that have adopted livestock facility siting ordinances, see DATCP website at http://datcp.wi.gov/Environment/Livestock_Siting/. Many counties have also adopted construction standards for manure storage facilities.
[224] *See* "Manure Spills in 2013 the Highest in Seven Years Statewide," *Milwaukee Journal-Sentinel* (December 5, 2013).
[225] 2010 DATCP staff estimate, based on "typical" livestock operation and applicable nutrient management standards.
[226] *See* U.S. Biogas LLC, note 221 *supra.*
[227] Per communication from the Wisconsin Land and Water Conservation Association.
[228] *See* U.S. Biogas LLC, note 221 *supra*.
[229] Dairy farms are the main source, but by no means the only source, of livestock manure in Wisconsin. Other kinds of manure, such as poultry manure, are important in some areas. Poultry manure can present serious management problems because of its geographic concentration and high phosphorus content.

[230] The synthetic nitrogen and phosphorus fertilizer used in Wisconsin originates from production facilities located outside the state. See The Fertilizer Institute, "U.S. Fertilizer and Mining Facilities at a Glance," available at http://www.kochfertilizer.com/pdf/TFI2009USProduction.pdf (visited February 2016). According to the Fertilizer Institute document, more than half of all nitrogen fertilizer used in the U.S. originates from foreign sources (the U.S. is the world's biggest importer of fertilizer).
[231] Method for estimating *nitrogen* from dairy manure: From American Association of Agricultural and Biological Engineers (ASABE), ASAE D384.2 (2005), Table 1.b., calculate average lbs. of nitrogen per lb. of manure (feces and urine, without dilutants) excreted by a lactating cow (calculation disregards potentially different nitrogen content of manure from dry cows, calves and replacement heifers). This calculation yields a unit-less ratio = 0.006618. Multiply this ratio by Wisconsin annual dairy manure production (estimated by the first method described in note 212, *supra*) to estimate total annual lbs. of nitrogen from dairy manure (rough estimate). Convert from lbs. to tons (to facilitate comparison with nitrogen fertilizer tonnage). For 2014, this calculation yields a statewide nitrogen contribution, from dairy manure, of about 209,000 tons.
[232] Method for estimating *phosphorus* from dairy manure: From American Association of Agricultural and Biological Engineers (ASABE), ASAE D384.2 (2005), Table 1.b., calculate average lbs. of phosphorus per lb. of manure (feces and urine, without dilutants) excreted by a lactating cow (calculation disregards potentially different phosphorus content of manure from dry cows, calves and replacement heifers). This calculation yields a unit-less ratio = 0.001147. Multiply by Wisconsin annual dairy manure production (estimated by the first method described in note 212, *supra*) to estimate total annual lbs. of phosphorus from dairy manure (rough estimate). Convert from lbs. to tons (to facilitate comparison with phosphorus fertilizer tonnage). For 2014, this calculation yields a statewide phosphorus contribution, from dairy manure, of about 36,000 tons.
[233] DATCP annual fertilizer tonnage report for 2014 (less than 5% non-farm use).
[234] See methodology, note 231 *supra.*
[235] See methodology, note 232 *supra.*
[236] Wisconsin has adopted nutrient management planning standards and requirements for farms, but compliance obligations are normally contingent on cost-sharing. *See* Wisconsin Administrative Code ch. ATCP 50. For information on nutrient management planning, see Wisconsin Department of Agriculture, Trade and Consumer Protection, "Nutrient Management," at http://datcp.wi.gov/Farms/Nutrient_Management/index.aspx.
[237] On many farms, soils already contain high levels of phosphorus. Legume crops, like soybeans and alfalfa, supply some of their own nitrogen needs by extracting nitrogen from the atmosphere. Some farms also get nutrients from treated municipal sewage products, such as Milwaukee's *Milorganite* or Madison's *Metrogrow*. Note that in areas where treated sewage products are used, they contribute a relatively small share of farm nutrients compared to commercial fertilizer and manure. *See* "A Clean Future for the Yahara Lakes: Solutions for Tomorrow, Starting Today," a joint report by Dane County, the City of Madison, DNR and DATCP (2010).
[238] *See* DATCP, "Wisconsin Making Inroads in Managing Manure," DATCP News Release (April 14, 2015).
[239] President Franklin D. Roosevelt, Letter to All State Governors on a Uniform Soil Conservation Law, February 26, 1937.
[240] *See* Arts and Church, "Soil Erosion – The Next Crisis?" *Wisconsin Law Review*, Volume 1982, No. 4 (1982); Pimental et al., "Environmental and Economic Costs of Soil Erosion and Conservation Benefits," *Science*, New Series, Vol. 267, No. 5201 (Feb., 1995), 1117-1123. See, also, the alarming (or alarmist?) *Scientific American* article quoting a senior United Nations Food and Agriculture Organization (FAO) official at http://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/.
[241] Pimental et al. (1995), note 240 *supra*.
[242] *See* discussion in Arts and Church, note 240 *supra*, at 545-52*.*
[243] *Ibid.*
[244] *See* U.S. EPA, "Nutrient Pollution: Sources and Solutions," available at http://www2.epa.gov/nutrientpollution/sources-and-solutions (April, 2015). Other citations can be found in Porter, et al., note 246 *infra*.

[245] USDA, 1989, cited in Pimental et al., note 240 *supra.*
[246] *See* Porter, et al., "Reducing hypoxia in the Gulf of Mexico: Reimagining a more resilient agricultural landscape in the Mississippi River Watershed," *Journal of Soil and Water Conservation* (May-June, 2015), 70-3, at 63A. *See also* "Moving Forward on Gulf Hypoxia," U.S. EPA Fact Sheet available at http://water.epa.gov/type/watersheds/named/msbasin/upload/2008_08_26msbasin_hypoxia_fs_508_0808.pdf; "Officials in Columbus discuss Midwest's role in Gulf of Mexico dead zone," *The Columbus Dispatch* (June 12, 2015).
[247] CNN News, "Gulf of Mexico 'Dead Zone' is the Size of Connecticut" (August 5, 2014).
[248] Egan, "Dead zones haunt Green Bay as manure fuels algae blooms," *Milwaukee Journal-Sentinel* (September 13, 2014).
[249] *See* Wisconsin DNR, "Reducing Phosphorus to Clean Up Lakes and Rivers" (Revised December 22, 2014).
[250] *See*, e.g., Wines, "Behind Toledo's Water Crisis A Long-Troubled Lake Erie" *New York Times* (August 4, 2014).
[251] Wisconsin DNR and U.S. EPA, "Wisconsin Integrated Assessment of Watershed Health" (March 2014).
[252] Wisconsin Initiative on Climate Change Impacts, *Soil Conservation Working Group Report* (2011).
[253] *Ibid.*
[254] Zuckerman, "Plowed Under," *The American Prospect*, 2014.
[255] University of Wisconsin Soils Department lecture, 2013 (Emeritus Prof. Kevin McSweeney).
[256] Wisconsin State Historical Society, Classroom Material "Wisconsin State Symbols," available at http://www.wisconsinhistory.org/Content.aspx?dsNav=N:4294963828-4294963805&dsRecordDetails=R:CS2908.