Better Nutrition, Better Tomorrow

breadfortheworld INSTITUTE

CHAPTER 3:
CHAMPIONING NUTRITION IN SUSTAINABLE CLIMATE-RESILIENT FOOD SYSTEMS

Hunger, malnutrition, and many other pressing global challenges are inextricably linked with climate change. Climate change could reverse decades of progress against global hunger and make it impossible to achieve the Sustainable Development Goals.

The Intergovernmental Panel on Climate Change (IPCC), established in 1988, is the global authority on climate science, with hundreds of climate experts from around the world contributing to its periodic assessments of climate change. The 2018 report features compelling evidence that there is very little time left to take the actions needed to avert catastrophic scenarios. Unless there is a much stronger global effort, it appears to be almost inevitable that Earth's temperature will increase by 2° Celsius (3.6° Fahrenheit) or more.[1] The IPCC expects that global warming will suppress the yields of all major staple crops. Tropical regions, where hunger and poverty are more widespread than other parts of the world, will experience the worst effects.[2]

Will the global community respond as needed? The adoption in 2015 of the Paris Climate Accord by virtually all the world's countries was a promising sign. Governments agreed to work together to limit global warming to 2° Celsius. Later, when additional evidence demonstrated the damage that 2° Celsius of warming would cause, the accord was amended to promote efforts to limit warming to 1.5° Celsius. The Paris Accord was weakened by the Trump administration's announcement that the United States would withdraw from it. In November 2020, the United States is scheduled to complete the final step in leaving the accord.

Sustainable food systems are an integral part of responding to the climate crisis. It may be helpful to define "sustainable food systems" as those that meet the needs of the present generation without undermining the ability of future generations to meet their own needs. This chapter has two objectives: to show why ending hunger and malnutrition are inseparable from environmental sustainability, and to explain what is needed for a more resilient global food system that will be capable of averting the worst-case scenarios of climate change.

Today's Food Production Carries Environmental Consequences

Global climate change is caused primarily by excess greenhouse gas emissions in the atmosphere. While many greenhouse gas emissions occur naturally, humans have disrupted the natural balance by causing large increases in emissions, driven by industrialization and population growth.

Feeding billions of people takes a toll on the natural environment. The global food system is responsible for up to 30 percent of greenhouse gas emissions.[3] Carbon dioxide, methane, and nitrous oxide are the primary emissions produced in food systems. The core components of the system that produce emissions include agriculture and land use, storage, transport, packaging, processing, retail, consumption, and waste.

RECOMMENDATIONS:

- Promote healthy, diversified diets that improve nutrition and reduce the environmental footprint of the food system.
- Redirect agricultural production subsidies and incentives to environmental stewardship to reduce the agricultural sector's contributions to greenhouse gas emissions and to help farmers adapt to and build resilience to changing climate conditions.
- Regenerate the natural resource base crucial for food production by reversing biodiversity loss, improving soil and water management, and establishing a moratorium on deforestation.
- Increase public and private sector research on the impact of climate change on nutrition and food systems. Ensure this research applies an equity lens, especially for race and gender.
- Integrate food systems and nutrition into national and international governance frameworks on climate change.

The largest source of greenhouse gas emissions in food systems is livestock raised for meat and dairy. Emissions from livestock production add more greenhouse gases to the atmosphere than the entire global transportation sector.[4] The five largest livestock producers combined are responsible for more emissions than ExxonMobil, Shell, or BP.[5] Beef cattle produce between 65 and 77 percent of all livestock emissions. Moreover, these emissions include methane, one of the most potent greenhouse gases. The second-largest source of emissions in food systems is food waste. If emissions from food waste were a country, it would be the third largest emitter in the world, behind only China and the United States.[6]

Industrial food systems rely on petrochemical-based synthetic fertilizers, pesticides, and herbicides to produce feed grain for livestock. The fossil fuels used to produce livestock feed have been described as "the food of our food." Worldwide, livestock consume one-third of all the grain produced,[7] and in some countries, such as the United States, the share of crops used as animal feed is even higher.

People in high-income countries consume, on average, more than enough animal protein. Recent reporting indicates that the average person in the United States eats 220 pounds of meat every year.[8] If the whole global population sought to consume this much, the world would run out of land to grow it: animal agriculture would require roughly twice as much land as Earth's total habitable land.[9] For people in low-income countries, where meat consumption is much lower, there are clear advantages to increasing consumption levels. Meat is rich in protein and provides essential micronutrients that are lacking in billions of people's diets (See Chapter 2).

Demand for livestock products is expected to increase in low- and middle-income countries as national incomes rise. Rising incomes are always associated with higher meat consumption.[10] China's meat consumption increased rapidly as more people could afford to buy it, and the Chinese population is expected to consume 27 percent of the global total by 2026.[11] The potential profits for agribusiness are immense. But as mentioned above, the meat and dairy industries are heavy producers of greenhouse gases; by mid-century, the increase in global demand for meat and dairy products is projected to cause an 80 percent increase in greenhouse gas emissions from food systems.[12]

One reason that livestock production contributes so heavily to climate change is that deforestation of the Amazon is motivated primarily by the desire to clear the land for cattle grazing. Deforestation is a major source of emissions, producing 10

BOX 3.1

KEY CONCEPTS IN THIS CHAPTER

Adaptation
"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." (UNFCC)

Biodiversity
"The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. Biodiversity forms the foundation of the vast array of ecosystem services that critically contribute to human well-being." (Millennium Ecosystem Assessment)

Climate change
"A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods." (UNFCC)

Greenhouse gases
"Greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and certain synthetic chemicals, trap some of the Earth's outgoing energy, thus retaining heat in the atmosphere. This heat trapping causes changes in the radiative balance of the Earth—the balance between energy received from the sun and emitted from Earth—that alter climate and weather patterns at global and regional scales." (EPA)

Mitigation
"In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases." (UNFCC)

Resilience
"The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure while also maintaining the capacity for adaptation, learning, and transformation." (IPCC)

Sustainability
"A dynamic process that guarantees the persistence of natural and human systems in an equitable manner." (IPCC)

Sustainable food system
"[A] food system that delivers food security and nutrition for all in such a way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised." (FAO)

percent of global carbon dioxide emissions. This is the equivalent of putting an additional 600 million cars on the road every year.[13] Because forests capture carbon dioxide from the atmosphere and sequester it, every acre of forest that is cleared also reduces Earth's ability to neutralize the effects of excess greenhouse gases.

Deforestation has caused staggering biodiversity losses as well. For example, most of California is considered a biodiversity hotspot, defined by Conservation International as a place with a high percentage of endangered plant and animal life found nowhere else on the planet.[14] California produces half of all agricultural products consumed in the United States each year.[15] Fires and drought linked to climate change are a direct threat to plant and animal habitats.

Another example of the damage caused by livestock production can be seen in the U.S. grain belt in the Midwest. The industrial production of animal feed, with its heavy reliance on chemical inputs, depletes soil of organic matter, which is an important part of food system biodiversity. Every summer, fertilizer runoff washes down the Mississippi River and creates a "dead zone" in the Gulf of Mexico. There is no surviving marine life in an area of about 5,000 square miles—roughly the size of Connecticut.[16]

Insects are an essential component of biodiversity, but today, more than 40 percent of all insect species are in danger of extinction, primarily because of the heavy use of synthetic pesticides and fertilizers.[17] "Insects are at the heart of every food web," says Dave Goulson, professor of biology at the University of Sussex. "They pollinate the large majority of plant species, keep the soil healthy, recycle nutrients, control pests, and much more."[18] Nearly all agricultural crops, including most fruits, vegetables, seeds, and nuts, depend on pollinators such as bees.[19] Heavy losses in U.S. honeybee colonies have been linked to the use of new classes of pesticides.[20] This is a major problem since honeybees pollinate more than 120 crops in the United States.[21]

People have known for decades that the chemical inputs used in industrial agriculture can have harmful effects. *Silent Spring*, Rachel Carson's seminal book about the dangers of the pesticide DDT, was published in 1962. Eventually, public concern led to a ban on the use of DDT, which had been in widespread use. This was a step forward, but as just discussed, pesticides other than DDT, as well as chemicals of different types, continue to cause problems but are still not regulated or banned.

The bottom line is that food systems depend on natural resources to meet current and future demand. Land, water, climate, and biodiversity are the building blocks of food systems. All food systems have these building blocks, but all food systems are not created equal when it comes to environmental footprints. Food systems with industrial-scale production practices are more harmful to the environment.

Emissions Steal Nutrients

In the past, climate scientists debated whether additional carbon dioxide might act as a fertilizer and increase food production. Today, the scientific consensus is the opposite.[22] Some areas will see increased crop yields, but overall, production of the major staple crops will decline.

Moreover, climate change affects the quality as well as the quantity of food. Rising levels of carbon dioxide in the soil and atmosphere lower the nutrient content of foods. Studies show, for example, that elevated levels of carbon dioxide reduce the amount of protein in food crops.[23] Based on projected carbon dioxide levels in 2050, climate scientists estimate that an additional 150 million people could suffer from protein-energy deficiency, virtually all of them in low- and middle-income countries.[24] This is an extremely dangerous condition that causes severe weight loss, weakens victims' immune systems, and often leads to death.

Another impact of excess carbon dioxide is that crops produce more simple carbohydrates at the expense of other important nutrients.[25] Lower vitamin and mineral content in crops puts hundreds of millions of people at risk of hidden hunger (See Chapter 2: Food, Nutrition, and Health).[26] For example, scientists project that by 2050, more than 130 million people will be at higher risk of zinc deficiency.[27] Zinc deficiency already causes an estimated 450,000 deaths among children every year.[28] A second example of the impact of elevated carbon dioxide is that there is less iron content in the crops grown. More than a billion women and 300 million children are expected to be at increased risk of iron-deficiency anemia.[29] Having iron-deficiency anemia doubles the risk that a woman will die during pregnancy or childbirth.[30]

The majority of carbon dioxide emissions in U.S. agriculture come from soil management.[31] Healthy soils are not only crucial to sequestering carbon, but also supply seeds, and in turn crops, with more nutrients. A carrot or an apple grown in the United States today is less nutritious than it was just a few decades ago, and the same holds true of most other foods grown from plants, according to U.S. Department of Agriculture (USDA).[32] By the end of the 20th century, a person needed to eat three apples to obtain the same amount of iron as eating just one apple grown during mid-century.[33]

Seafood is a major source of protein and micronutrients for people who live in tropical areas near the sea. People in coastal indigenous communities consume nearly four times as much seafood as the rest of the global population.[34] But nearly a third of fish stocks are already overfished,[35] and climate change may reduce fishers' catch by up to 40 percent.[36] Some communities are especially vulnerable because there are few dietary alternatives.

With climate change, the world is seeing more heat waves and droughts, and they are also more severe. Foods lose their

nutritional content and spoil more quickly. While livestock can generally adapt to heat better than planted crops, there are clear limits. Stress from extreme heat causes dairy cows to produce lower quality milk[37] and poultry to lay fewer eggs.[38] Industrial production systems adapt by housing animals in environmentally controlled facilities. Smallholder farmers do not have this option. Loss of livestock is devastating to families who may have few or no other assets—or sources of protein-rich foods such as eggs.

Dry parts of the world will become drier, while wet areas will become wetter, as is already underway (See Figure 3.1). Both conditions will affect water quality, leading to outbreaks of diarrhea associated with stunting and child wasting. Climate change is predicted to lead to rising food prices, with regional variations of 1-30 percent, according to the IPCC, putting as many as 183 million additional people at risk of hunger by 2050.[39]

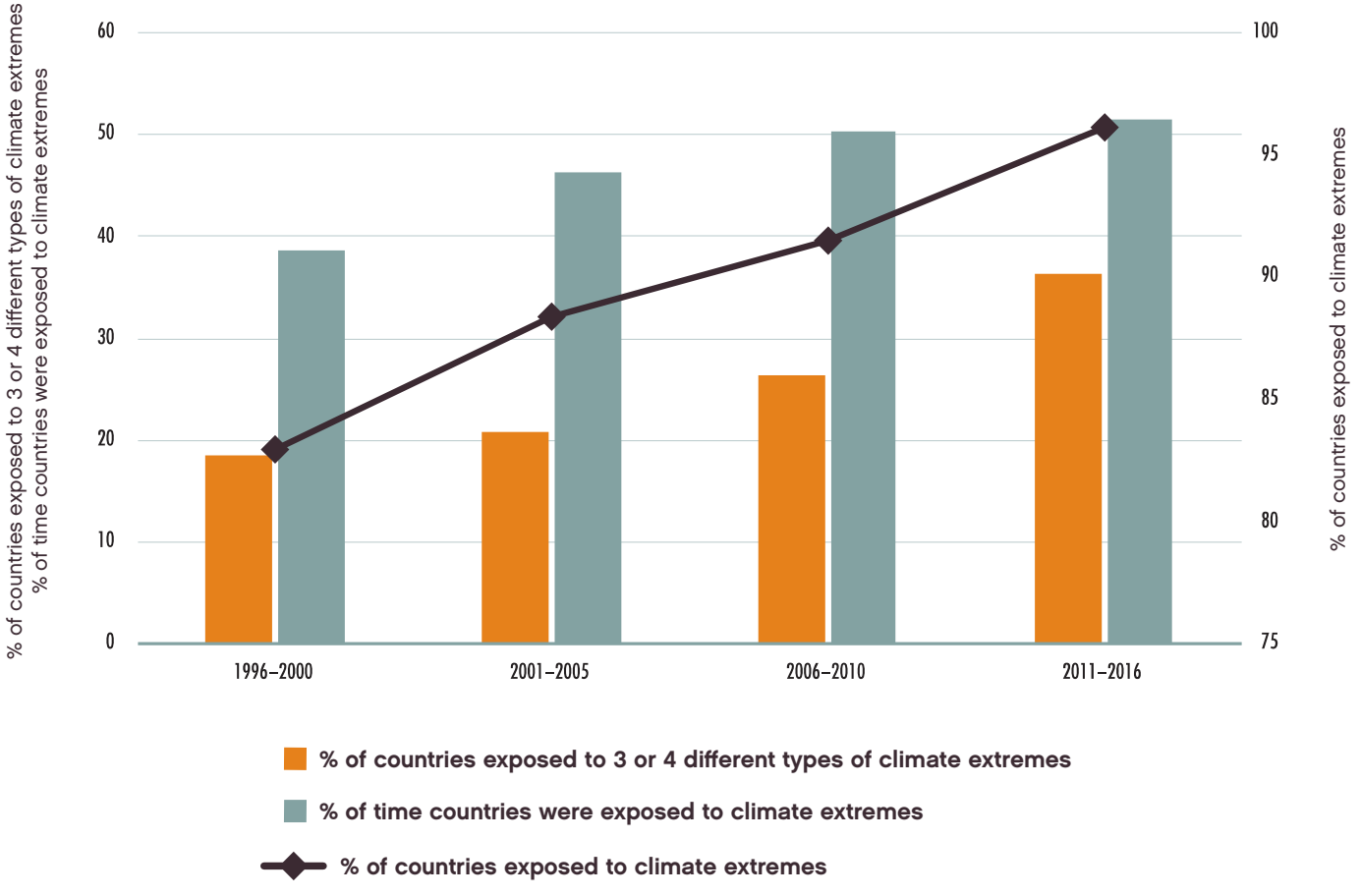
Hunger is already more common in countries with climate extremes such as droughts, floods, and cyclones. As of 2017, the average hunger rate in those countries as a group was 42 percent higher than the hunger rate for all countries of the world combined. In countries considered the most vulnerable to climate change, the absolute hunger rate was far higher than the global average—25.2 percent compared to 10.8 percent worldwide.[40]

Prioritizing Sustainable Food Production and Consumption

The global community must commit to reducing greenhouse gas emissions or face environmental impacts that will change human life in ways that are almost unimaginable from the vantage point of 2020. Countries need both adaptation and mitigation strategies to combat the effects of climate change. Sustainable food systems strategies must include both food production and food consumption.

FIGURE 3.1

Low- and middle-income countries face increased exposure to more frequent and multiple types of climate extremes



Source: FAO, 2018

Sustainable Production

Smallholder farmers and their communities are especially vulnerable to the effects of climate change because they eat mainly what they are able to grow. Some national governments have plans to help smallholders adapt to climate change but lack the resources to implement them.

Adaptation focuses on strategies to increase farmers' resilience to the changing climate conditions, whether they are traditional practices or innovative technologies. When it comes to helping smallholder farmers adapt to climate change, there are fewer barriers to traditional knowledge and practices, whereas there may be quite large barriers to accessing technology, especially for women (See Chapter 4: The Female Face of Food Systems).

Improving soil quality may involve new technologies, but it doesn't have to when traditional practices will suffice. The traditional practice of diversified cropping is healthier for soils than monocropping, requiring less application of chemical inputs. Globally, one-third of agricultural land is moderately to highly degraded.[41] Moreover, diverse production systems contribute essential nutrients to the food supply and also make farmers less vulnerable to catastrophic losses.[42]

U.S. farmers would do well to diversify their own cropping systems. Cropland soil in the United States is eroding 10 times faster than it is being replenished.[43] Monocropping of feed grains leads to substantial soil biodiversity losses. In turn, loss of biodiversity limits the soil's capacity to sequester carbon. U.S. farm policy has too few incentives for farmers to diversify their crops and improve their soil—and too many incentives not to change. Even though conservation practices pay for themselves in the long run, the initial investment discourages farmers from adopting them.[44] Before the 2018 farm bill was enacted, farmers received federal conservation funding to improve soil health for only 2 percent to 5 percent of all U.S. cropland[45] —and there was no additional funding in the new farm bill.[46]

To produce food sustainably, it is not necessary that farmers eliminate all chemical inputs. Sustainable agriculture is not the same as organic agriculture, which is more prescriptive as to what practices farmers must follow. Organic farming is not even necessarily more climate friendly. Based on how land is managed, organic farms may produce higher greenhouse gas emissions than the same size operations using conventional farming methods.[47]

Technology is central to the land management strategy known as precision agriculture. Fertilizer applied in precise doses is preferable to dousing crops with more than is needed. Precision agriculture uses advanced technologies such as robotics and artificial intelligence to farm more sustainably, although critics charge it does not make farming more equitable. "The problem with precision agriculture is that it's going to be very expensive and capital intensive, and it's already a capital intensive business," explains Mark Rasmussen, director of the Leopold Center for Sustainable Agriculture at Iowa State University.[48] (See Chapter 1: Giant Combines and Smallholder Farmers)

The emissions footprint of food is complicated and involves how food is produced, where and when it is produced, and the route it has to take to reach consumers. Shorter food chains can lower total emissions since, for example, transporting food for long distances by truck generates large amounts of greenhouse gas emissions. Fruits and vegetables grown in the United States travel an average of 1,500 miles to reach American consumers.[49] Shorter food chains are not always the best choice for the climate, however. If the foods are not grown in sustainable ways, it may be better to buy from a source further away but more efficient. One study, for example, showed that foods grown out of season in Spain produced more emissions than the same foods imported from Africa.[50]

Earlier in this report, we discussed the infrastructure necessary for smallholders to reach urban markets. (See Chapter 1: Market Links: Between Production and Consumption). Greenhouse gas emissions make it more complicated to do a cost-benefit analysis and decide which transportation options to recommend to growers. Building road and rail networks generates high levels of greenhouse gases. The good news is that there is no shortage of innovative ideas for alternative solutions.

Airship technology powered by helium or solar energy is a low-emission alternative that could transport food out of rural areas. Research is underway to help solve the problem of food that spoils before it gets to market by formulating plant-based coatings that can keep fruits and vegetables fresh for days, in some cases weeks, with no discernible effect on taste.[51] Cryogenic energy storage is a fossil-free alternative to conventional refrigerants for use in cold chains. Some of these may seem far removed from the technologies available in the daily lives of smallholder farmers. Yet, communities have successfully "leapfrogged" to newer technologies before. Think of all the telephone poles that did not need to be built because cellphone technology reached rural areas of Africa and Asia. Cellphones also enable rural people to access banking services.

Indoor urban agriculture has not received much attention from researchers, but climate change may spark more interest. Urban agriculture can potentially give city residents more influence over what foods are available to them, as well as better options when climate-related disasters cause sudden price spikes. Little research has been done on the efficiency of large-scale urban agriculture projects, such as those that occupy entire buildings, in part because only recently has the concept received serious attention.[52] As urbanization absorbs more land, driving up land prices and making community gardens less accessible, indoor facilities are looking more attractive by comparison.

Fruits and vegetables can be grown indoors. Producing more of these crops, whether indoors or outdoors, will lead to lower prices. With more being produced and offered at lower prices, people will have more access to a nutritious diet.

Sustainable Consumption

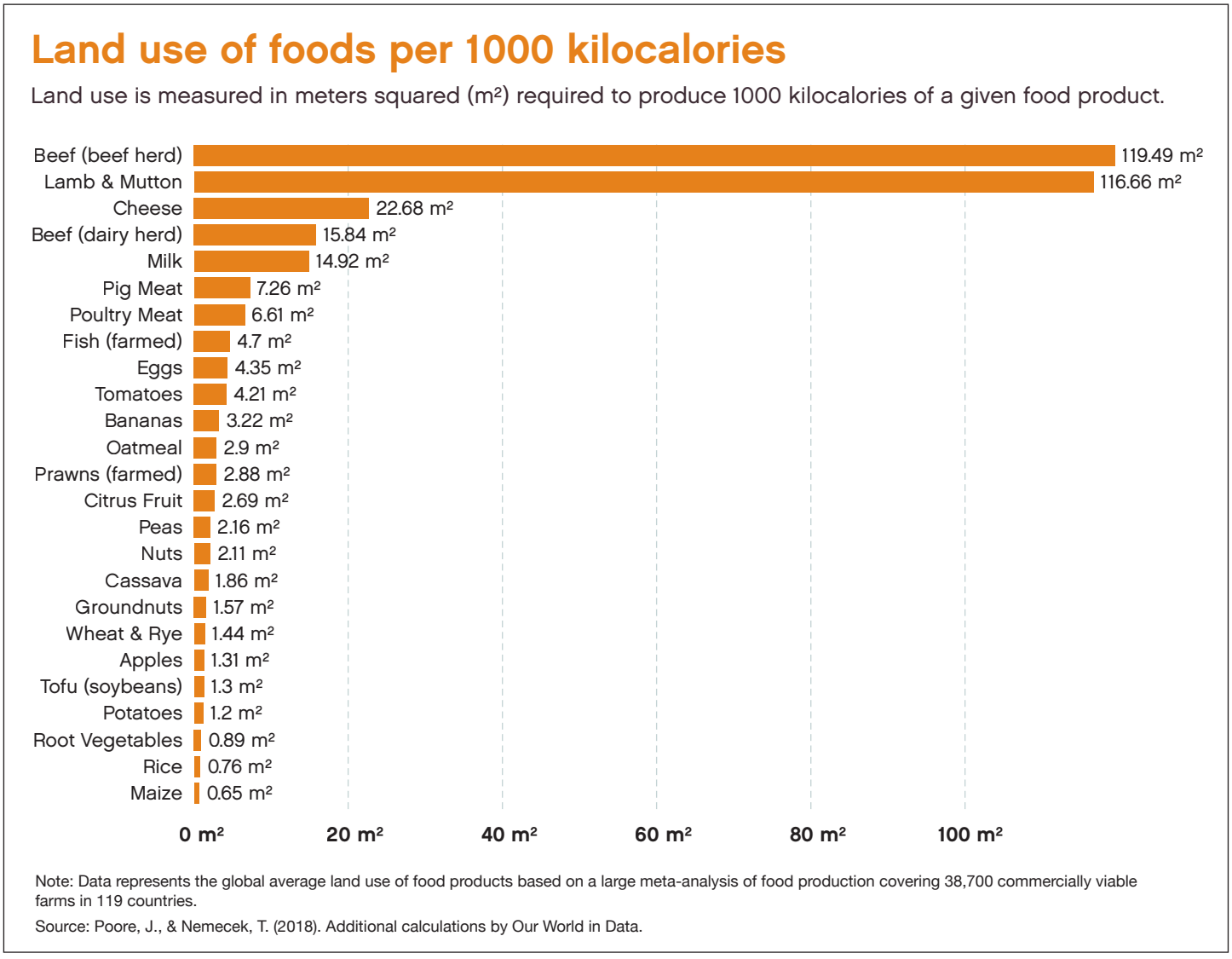
Sustainable food systems with low environmental impacts require changes on the consumption side as well. Demand-side changes in food choices that influence consumption patterns have the potential to reduce emissions while improving health. Nobody should underestimate health as an adaptation strategy. Good health means people are more agile to escape danger, as when a hurricane strikes or during a heat wave.

As we noted earlier, it is not necessary for everyone to become vegetarian, but, according to the Global Panel on Agriculture and Food Systems, reducing meat consumption in favor of plant-based foods could significantly reduce greenhouse gas emissions in food systems.[53] This is because it requires much less land to produce enough calories and nutrients to feed the world a plant-based diet (See Figure 3.2). In addition to generating more greenhouse gas emissions, meat-centered diets are less healthy than diets of plant-based foods such as fruits and vegetables, whole grains, legumes, and nuts.[54]

The most important consideration when it comes to meat is for high-income countries to reduce their consumption. According to the IPCC, "A 15 percent reduction of animal products in the diets of high-income countries by 2050 would contribute to containing the need to expand agricultural output due to upward global demographic trends. Not only would greenhouse gas emissions and the pressure on land and water be significantly reduced, but the potential for low-income countries to increase [their] intake of animal-based food, with beneficial nutritional outcomes, could be enhanced."[55]

Because of its large population, the United States could make a significant difference to climate change by reducing its meat consumption. Another reason the United States is so important on this issue is that Americans eat more meat than people

FIGURE 3.2



Note: Data represents the global average land use of food products based on a large meta-analysis of food production covering 38,700 commercially viable farms in 119 countries.

Source: Poore, J., & Nemecek, T. (2018). Additional calculations by Our World in Data.

in many other developed countries. The average U.S. resident consumes roughly 2.5 times as much red meat as people in the United Kingdom and the European Union.[56] The history of red meat consumption also offers hope for change. U.S. meat consumption has decreased by one-third since the 1970s, which was when public health officials first began to report the connection between overconsumption and death from heart disease. Consumption patterns can, in fact, change in response to new information.[57]

One way to encourage a faster transition is to focus on children. Human dietary preferences are formed during childhood, so the younger people are when they are exposed to diverse nutritious foods, the better. School systems are beginning to raise awareness and make a generational shift to align children's diets with environmental sustainability—for example, by participating in new "traditions" such as Meatless Mondays. New York City has the largest public school system in the country, making it an important bellwether of nationwide trends. In 2019, the city began offering every student in its 1,800 public schools a free vegetarian lunch one day a week.[58]

Efforts are also being made to help adults transition to eating less meat. For example, many more alternative meat options, with much better taste and appearance, have recently hit the market. Many meat lovers admit they can no longer tell the difference between a grilled hamburger and a grilled lab-grown burger. Some of the products are vegetarian, while some use animal cells and multiply them in a high-tech factory setting to create actual meat and seafood, bypassing the slaughterhouses. Investment is soaring in these products, and the cattle industry is so concerned about the rising popularity of lab-grown alternatives that it is fighting to prevent lab-grown products from being labeled as meat.[59]

The U.S. dietary guidelines are the basis for many food and nutrition policies. Because of their influence on the foods and beverages served in schools, for example, promoting nutritious foods in the dietary guidelines is another way of shaping children's food preferences and eating habits for the rest of their lives.[60] Many high-income countries are embracing food-based dietary guidelines that explicitly link health and sustainability. Few low- and middle-income countries have food-based dietary guidelines in place,[61] so supporting governments in developing and implementing them also contributes to building climate-friendly food systems. In the United States, formulating the national dietary guidelines is one of the rare instances of cooperation on policy between USDA and the U.S. Department of Health and Human Services. Thus far, this has been a missed opportunity to move toward effective climate response in the U.S. food system—a missed opportunity that the planet cannot afford.

The committee that drafted the 2015–20 Dietary Guidelines for Americans sought to link healthy eating with sustainability. A preliminary draft defined a sustainable diet as "a pattern of eating that promotes health and well-being and provides food security for the present population while sustaining human and natural resources for future generations."[62] However, the meat industry lobbied hard against any mention of sustainability in the guidelines,[63] and the sustainability language was struck from the final version—against the overwhelming advice of doctors, scientists, and nutritionists.[64]

At this writing, committee work is in progress to develop the 2020-2025 Dietary Guidelines, but the policy environment has worsened. After the last set of guidelines was released, industry lobbyists succeeded in persuading Congress to enact legislation that limits the scope of the guidelines to diet, defined in a narrow way that excludes consideration of sustainability or climate.[65]

Bringing on the Sustainable Future

As the example of the Dietary Guidelines for Americans shows, it is critically important, but far from easy, to "first, do no harm." Governments must stop supporting policies that worsen the climate crisis.

Governments of the leading food-producing nations spend nearly half a trillion dollars on farm subsidies every year. Most of the money supports the production of beef and dairy products.[66] Operators of large farms that produce animal feed are the biggest beneficiaries in the United States. For all their rhetorical support for the Paris Climate agreement, officials of European Union countries have done little better. The EU farm sector has not reduced its emissions since 2010.[67]

The problem in fossil fuel industries is literally 10 times bigger: in an average year, governments pay $5 trillion in subsidies to fossil fuel industries.[68] For decades, the farm sector and fossil fuels industries have been closely aligned in opposition to substantive climate legislation. Because industrial food production systems are so energy intensive, the largest and most politically influential stakeholders fear that efforts to reduce greenhouse gas emissions will lead to higher fuel and fertilizer costs. The American Farm Bureau Federation, the largest farmer organization in the United States, has not only been a consistently loyal defender of fossil fuels, but has publicized and promoted misinformation about climate science that fossil fuel interests have generated.[69]

Farmers are, however, acutely aware of the true conditions on the land. Of the last 22 years, 20 were the hottest on record.[70] In 2019, large areas of the United States had record-breaking amounts of precipitation. The heavy rain and flooding prevented farmers from planting more than 19 million acres.[71] Concepts such as the 100-year flood or the 500-year flood no longer have any meaning.

"Science is telling us that the climate is changing. I see it happening before my very eyes," said Fred Yoder, a fourth-gener-

ation farmer from Ohio who was invited to testify at a 2019 congressional hearing on the climate crisis. "Science isn't perfect," he added, "but it's the very best tool we have to make assessments, and the science on this topic is clear."[72]

As former chair of the National Corn Growers Association, Yoder is part of the community, an insider. "When I talk to fellow farmers about climate change," he explained, "I don't talk about what they can do or need to do to save the planet; I talk about innovative practices and systems that help their economic and environmental bottom lines."[73] Yoder is co-chair of Solutions for the Land, an organization made up of agricultural leaders committed to climate-smart agriculture: reducing greenhouse gases sector-wide while supporting individual farmers to adapt and build resilience to climate change.[74]

Resolving environmental and climate challenges within food systems depends on farmers (See Climate-smart Agriculture on Maryland's Eastern Shore). Federal policies must recognize this and champion them as crucial partners. To slow climate change, land use policies must transition U.S. farmland as rapidly as possible from a net source of emissions to a net supplier of carbon sequestration.

At the heart of the Paris Climate Accord is the need to close the gap between current levels of greenhouse gas emissions and the levels needed to avoid the worst climate change impacts. More than half the land in the United States is used for agriculture.[75] The U.S. government should be investing in farmers who are willing and able to meet the sustainability standards that climate scientists agree are necessary to cope with climate change. As mentioned above, effectively managing soil and land use to maximize carbon sequestration should be the top priority. This can be accomplished on a large scale at a relatively low cost, and farmers would benefit immediately from improved soil quality.[76]

Another key step to avoid making the problem worse is to enforce and, as necessary, tighten standards for emissions. Most large food companies underreport emissions data by not counting emissions across the whole food chain. These are significant omissions, according to research from GRAIN and the Institute for Agriculture and Trade Policy. Their analysis of the world's 35 largest beef, pork, poultry, and dairy companies found that only four of the companies provided comprehensive emissions estimates.

According to *The Lancet* in a landmark report on malnutrition and climate change, the single biggest contribution that corporations could make would be to "stop investing enormous efforts and resources into opposing the enactment of regulations and fiscal policies for the public good."[77]

But the planet cannot wait until corporations decide to stop hindering necessary climate measures and voluntarily reduce their greenhouse gas emissions. As just explained, many have been successful so far in preventing any significant regulations aimed at slowing climate change. Governments must face the facts and take the needed legislative and regulatory actions to protect the public good writ large: life on Earth.

Finally, a word about research. The public sector is a vital piece of the puzzle in funding for agricultural research related to climate change. This is because research supported by industry often reports findings that advance its funder's goals. For example, a company that sells pesticides and fertilizers is not likely to fund research focused on how farmers can use less of their products. One notable exception has been biofortification to increase the vitamin and mineral content of staple crops.

Agricultural science offers countless ways to reduce malnutrition in tough environments. Micronutrient fertilizers can improve the nutritional quality of crops produced in degraded soil. HarvestPlus, a leading organization in the field of biofortification, has developed multiple varieties of biofortified crops using traditional breeding practices, including Vitamin-A enriched orange sweet potato in East Africa and iron-enriched millet in India. Both are drought-tolerant crops.

Historically, the focus of most agricultural research has been on increasing the yields of staple crops.[78] The research needed now will identify crops that are highly nutritious and resilient to climate change as well as how best to grow them. We need to know more about a broader range of crops. There are many neglected and underutilized crops that are rich in vitamins and minerals and can grow in tough conditions. Some or all of them could become more commonly eaten foods as a result of climate change.

Up Next

In the next section, we consider ways of advancing equity in food systems. Sustainable food systems should enable all people to benefit from nutritious and healthy food. This will not happen without special efforts to ensure equitable outcomes. Vulnerable populations require more support. Food systems are an ideal venue to address the root causes of social, economic, and political powerlessness.

Ironies abound in the global food system. Much of the food we consume that should be essential to our health is making us sick, and the environment we rely on to produce food is being destroyed at a rate we may never be able to replenish. Here's another to ponder. All over the world, the people who are essential to nourishing their communities are most likely to be malnourished and vulnerable to hunger. The global food system is defined by this paradox. In Chapter 4, we'll take a closer look at it.

Endnotes

1 Intergovernmental Panel on Climate Change. 2018. Special Report: Global Warming of 1.5°C. https://www.ipcc.ch/sr15/

2 Carl-Friedrich Schleussner et al. 2018. Crop productivity changes in 1.5 °C and 2 °C worlds under climate sensitivity uncertainty. *Environmental Research Letters* Volume 13 Number 6. https://iopscience.iop.org/article/10.1088/1748-9326/aab63b/pdf

3 Intergovernmental Panel on Climate Change. 2019. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Chapter 5: Food Security. https://www.ipcc.ch/report/srccl/

4 P.J. Gerber et al. 2013. Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities. FAO: Rome. http://www.fao.org/3/a-i3437e.pdf

5 Shefali Sharma. November 30, 2018. Livestock's contribution to the 1.5°C Pathway. Institute for Agriculture & Trade Policy. https://www.iatp.org/documents/livestocks-contribution-15c-pathway-0

6 FAO. 2015. Food Wastage and Footprint & Climate Change. http://www.fao.org/3/a-bb144e.pdf

7 Mark C. Eisler and Michael R. F. Lee 2014. Steps to Sustainable Livestock. *Nature*, Vol. 507. https://www.nature.com/news/agriculture-steps-to-sustainable-livestock-1.14796

8 Hannah Ritchie. February 2019. Which countries eat the most meat? BBC News. https://www.bbc.com/news/health-47057341

9 Peter Baker et al. 2016. Human appropriation of land for food. The role of diet. Global Environmental Change Volume 41:88-98. https://www.sciencedirect.com/science/article/abs/pii/S0959378016302370?via%3Dihub

10 Pierre Sans and Pierre Combris. 2015. World meat consumption patterns: An overview of the last fifty years (1961-2011). Meat Science Volume 109: 106-111. https://www.sciencedirect.com/science/article/abs/pii/S0309174015300115?via%3Dihub

11 U.S. Department of Agriculture. 2018. USDA Agricultural Projections to 2027. https://www.ers.usda.gov/webdocs/publications/87459/oce-2018-1.pdf?v=43146%20

12 Janet Ranganathan et al. 2016. "Shifting Diets for a Sustainable Food Future." Working Paper, Installment 11. World Resources Institute. https://www.wri.org/sites/default/files/Shifting_Diets_for_a_Sustainable_Food_Future_1.pdf

13 Christopher Flavelle. August 8, 2019. "Climate Change Threatens the World's Food Supply, UN Warns," *The New York Times*. https://www.nytimes.com/2019/08/08/climate/climate-change-food-supply.html

14 Conservation International: Biodiversity Hotspots. https://www.conservation.org/How/Pages/Hotspots.aspx

15 Critical Ecosystem Partnership Fund: California Floristic Province – Threats. https://www.cepf.net/our-work/biodiversity-hotspots/california-floristic-province/threats

16 Doyle Rice. June 10, 2019. "Near-record dead zone predicted in the Gulf of Mexico this summer." *USA Today*. https://www.usatoday.com/story/news/nation/2019/06/10/dead-zone-near-record-zone-forecast-gulf-mexico/1407088001/

17 Francisco Sanchez-Bayo and Kris A.G. Wyckhuys. 2019. Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, Volume 232, pp.8-27. https://www.sciencedirect.com/science/article/pii/S0006320718313636

18 Damian Carrington. February 10, 2019. Plummeting insect numbers 'threaten collapse of nature.' *The Guardian*. https://www.theguardian.com/environment/2019/feb/10/plummeting-insect-numbers-threaten-collapse-of-nature

19 Simon G. Potts et al. 2016. Safeguarding pollinators and their values to human well-being. *Nature* 540, 220-229. https://www.nature.com/articles/nature20588

20 Liza Gross. January 23, 2019. Bees face yet another lethal threat in dicamba, a drift-prone pesticide. Reveal. Center for Investigative Reporting. https://www.revealnews.org/article/bees-face-yet-another-lethal-threat-in-dicamba-a-drift-prone-pesticide/

21 U.S. Department of Agriculture. June 22, 2016. Fact Sheet: Research and Outreach at ISDA Keeps Pollinators Buzzing. https://www.usda.gov/media/transcripts-speeches/2016/06/23/fact-sheet-research-and-outreach-usda-keeps-pollinators

22 IPCC. 2019. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Chapter 5: Food Security. https://www.ipcc.ch/report/srccl/

23 *Science Daily*. August 27, 2018. "As CO2 Levels climb, millions at risk of nutritional deficiencies." https://www.sciencedaily.com/releases/2018/08/180827180806.htm

24 Danielle E. Medek, Joel Schwartz, and Samuel S. Myers. 2017. Estimated Effects of Future Atmospheric Co2 Concentrations on Protein Intake and the Risk of Protein Deficiency by Country and Region. Environmental Health Perspectives Vol. 125, No. 8. https://ehp.niehs.nih.gov/doi/10.1289/EHP41

25 Ineke Mules. 2018. Climate Change strips nutrients from food crops. DW. https://www.dw.com/en/climate-change-strips-nutrients-from-food-crops/a-44161873

26 Samuel S. Myers et al. 2017. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*. 38: 259-77. http://environment.harvard.edu/sites/default/files/climate_change_and_global_food_systems_impacts_on_food_security_and_undernutrition.pdf

27 Global Panel on Agriculture and Food Systems for Nutrition. 2016. Foresight Report on Food Systems and Diets: Facing the Challenges of the Twenty-first Century. London, UK. https://glopan.org/sites/default/files/ForesightReport.pdf

28 Robert E. Black and Crista L. Fischer Walker. 2012. Role of zinc in child health and survival. Nestle Nutrition Institute Workshop: Meeting Micronutrient Requirements for Health and Development, vol. 70, pp 37-42. https://www.karger.com/Article/Abstract/337393

29 Matthew R. Smith and Samuel S. Myers. 2018. Impact of anthropogenic CO2 emissions on global human nutrition. *Nature Climate Change* Vol. 8, 834-839. https://www.nature.com/articles/s41558-018-0253-3.epdf?referrer_access_token=U9I9ylghWQszPPMsbuOs5tRgN-0jAjWel9jnR3ZoTv0O5J0oP_LhVUOgym62AyF5ghuOS5aOCa4g0Agd33biHRPVvzshteI-I8s6f0432vmaDtwx28IbA_1rUF6bUFrcpPQmlkW8yIrssI3hK9jpJ8kZzTEIuIQmPgiyqj0F-Pn0ncunCPKX2u6ikr5IkKTJfRKB6Nk_AJt0lw9Z701SZMl9BwrSre6lOjBS9yodCaoCZb27oS-0b16hW-aotQByRPF9Q5WAUeDWZwmZqFd6sg34DavohtVDVExWGF3wNLJFM0pqwjzX-G9ULrw7uEV5geLZT&tracking_referrer=www.theguardian.com

30 Huizhong Wu (March 20, 2018), "Anemia doubles risk of deaths for pregnant women, study finds," *CNN*. https://www.cnn.com/2018/03/20/health/anemia-pregnancy-deaths-study/index.html

31 Marci Baranski et al. 2018. Agricultural Conservation on Working Lands: Trends From 2004 to Present. U.S. Department of Agriculture. https://www.usda.gov/oce/oeep/USDA_Conservation_Trends.pdf

32 Donald R. Davis, Melvin D. Epps, and Hugh D. Riordan. 2004. Changes in USDA Food Composition Data for 43 Garden Crops, 1950-1999. *Journal of the American College of Nutrition*, Vol 23, No 6 669-682. http://saveoursoils.com/userfiles/downloads/1351255687-Changes%20in%20USDA%20food%20composition%20data%20for%2043%20garden%20crops,%201950-1999.pdf

33 Brian Halweil. 2007. Still No Free Lunch: Nutrient levels in U.S. food supply eroded by pursuit of high yield. The Organic Center. https://www.organic-center.org/reportfiles/Yield_Nutrient_Density_Final.pdf

34 Yoshitaka Ota and Andres Cisneros-Montemaypr. January 29, 2017. For indigenous communities, fish mean more than food. *The Conversation*. https://theconversation.com/for-indigenous-communities-fish-mean-much-more-than-food-70129

35 Food and Agriculture Organization of the United Nations (2019), *State of the World's Biodiversity for Food and Agriculture*. Rome. http://www.fao.org/3/CA3129EN/CA3129EN.pdf

36 FAO. 2018. The State of World Fisheries and Aquaculture: Meeting the Sustainable Development Goals. http://www.fao.org/3/i9540en/I9540EN.pdf

37 Andrea Sumner et al. 2018. Impact of heat stress on milk and meat production. *Animal Frontiers*, Vol. 9, Issue 1, pp 39-46. https://academic.oup.com/af/article/9/1/39/5145101

38 Lucas J. Lara and Marcus H. Rostagno. 2013. Impact of Heat Stress on Poultry Production. *Animals* 3:356-369. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4494392/

39 Intergovernmental Panel on Climate Change. 2019. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Chapter 5: Food Security. https://www.ipcc.ch/report/srccl/

40 Intergovernmental Panel on Climate Change. 2019. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Chapter 5: Food Security. https://www.ipcc.ch/report/srccl/

41 Food and Agriculture Organization of the United Nations (2019), *State of the World's Biodiversity for Food and Agriculture*. Rome. http://www.fao.org/3/CA3129EN/CA3129EN.pdf

42 Mario Herrero et al. 2017. Farming and the geography of nutrient production for human use: a transdisciplinary analysis. *The Lancet Planetary Health*. Volume 1, Issue 1: e33-e42. https://www.sciencedirect.com/science/article/pii/S2542519617300074

43 Susan Cosier. May 30, 2019. The world needs topsoil to grow 95% of its food—but it's rapidly disappearing," T*he Guardian*. https://www.theguardian.com/us-news/2019/may/30/topsoil-farming-agriculture-food-toxic-america

44 Brian Barth (June 28, 2019), One man is trying to save the world from climate change by mobilizing an unlikely team: Iowa's farmers. *Food and Environment Reporting Network*. https://thefern.org/2019/06/one-man-is-trying-to-save-the-world-from-climate-change-by-mobilizing-an-unlikely-team-iowas-farmers/

45 Leopold Biardeau et al. 2016. Soil Health and Carbon Sequestration in US Croplands: A Policy Analysis. Goldman School of Public Policy, University of California Berkley. https://food.berkeley.edu/wp-content/uploads/2016/05/GSPPCarbon_03052016_FINAL.pdf

46 National Sustainable Agriculture Coalition. January 2019.A Closer Look at the 2018 Farm Bill: Working Lands Conservations Programs. NSAC's Blog. http://sustainableagriculture.net/blog/a-closer-look-at-the-2018-farm-bill-working-lands-conservation-programs/

47 Verena Suefert and Navin Ramankutty 2017. Many shades of gray—The context-dependent performance of organic agriculture. *Science Advances*. 3(3): e1602638. https://advances.sciencemag.org/content/3/3/e1602638

48 Georgina Gustin. January 25, 2019. Industrial Agriculture, an Extraction Industry Like Fossil Fuels, a Growing Driver of Climate Change. *Inside Climate News*. https://insideclimatenews.org/news/25012019/climate-change-agriculture-farming-consolidation-corn-soybeans-meat-crop-subsidies

49 Johns Hopkins Center for a Livable Future: Food Distribution. http://www.foodsystemprimer.org/food-distribution/index.html

50 Maria Tobarra et al. 2018. Is Seasonal Households' Consumption Good for the Nexus Carbon/WaterFootprint? The Spanish Fruits and Vegetables Case. *Environmental Science & Technology*. 52(21): 12066-12077. https://pubs.acs.org/doi/10.1021/acs.est.8b00221

51 Bill Gates (March 26, 2019), "We should discuss soil as much as we talk about coal," *Gates Notes*, the blog of Bill Gates. https://www.gatesnotes.com/Energy/We-should-discuss-soil-as-much-as-coal

52 Pinstrup-Andersen in UNSCN. 2019. Food Environments: Where people meet the food system. *Nutrition* 44. https://www.unscn.org/uploads/web/news/UNSCN-Nutrition44-WEB.pdf

53 Marco Springmann et al. (April 12, 2016), Analysis and valuation of the health and climate change co-benefits of dietary change," *Proceedings of the National Academy of Sciences*, vol. 113, no. 15. http://www.pnas.org/content/pnas/113/15/4146.full.pdf

54 H. Charles J. Godfray and Tara Garnett. 2014. Food security and sustainable intensification Philosophical Transaction of the Roya Society. https://royalsocietypublishing.org/doi/full/10.1098/rstb.2012.0273

55 Intergovernmental Panel on Climate Change. 2019. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Chapter 5: Food Security. https://www.ipcc.ch/report/srccl/

56 Organization for Economic Cooperation and Development: Meat Consumption. https://data.oecd.org/agroutput/meat-consumption.htm

57 Richard Waite. January 24, 2018. 2018 Will See High Meat Consumption in the U.S., but the American Diet is Shifting. Blog. World Resources Institute. https://www.wri.org/blog/2018/01/2018-will-see-high-meat-consumption-us-american-diet-shifting

58 JoAnna Klein. November 22, 2019. "What happens when the largest school system goes meatless one day a week?" *The Hill*. https://thehill.com/changing-america/sustainability/climate-change/471698-what-happens-when-the-nations-largest-school

59 Nathan Popper. February 9, 2019. "You Call That Meat? Not So Fast, Cattle Ranchers Say." *The New York Times*. https://www.nytimes.com/2019/02/09/technology/meat-veggie-burgers-lab-produced.html

60 HLPE. 2017. Nutrition and food systems. A report by the High-Level Panel on Food and Nutrition of the Committee on World Food Security, Rome. http://www.fao.org/3/a-i7846e.pdf

61 United Nations Standing Committee on Nutrition. June 2018. Advancing equity, equality, and nondiscrimination in food systems: Pathways to reform. *USCN News* 43. Kennedy and Fanzo, "Overweight, obesity, and the food environment: Are there solutions?" pp 43-48. https://www.unscn.org/uploads/web/news/UNSCN-News43-WEB.pdf

62 Donald Rose, Martin C Heller, Christine A Roberto. 2019. Position of the Society for Nutrition Education and Behavior: The Importance of Including Environmental Sustainability in Dietary Guidelines. *Journal of Nutrition Education and Behavior*, Vol 51, Number 1. https://www.jneb.org/article/S1499-4046(18)30673-0/pdf

63 James Hamlin. 2015. How Agriculture Controls Nutrition Guidelines, *The Atlantic*. https://www.theatlantic.com/health/archive/2015/10/ag-v-nutrition/409390/

64 Natalie Wood-Wright. 2016. New U.S. dietary guidelines ignore broad support for food sustainability. Johns Hopkins Center for a Livable Future. https://hub.jhu.edu/2016/03/11/dietary-guidelines-sustainability-survey/

65 Union of Concerned Scientists. June 2019. *Delivering on the Dietary Guidelines: How Stronger Nutrition Policy Can Cut Healthcare Costs and Save Lives*. https://www.ucsusa.org/sites/default/files/attach/2019/06/delivering-on-the-dietary-guidelines-report.pdf

66 *The Lancet*. 2019. The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. https://www.thelancet.com/commissions/global-syndemic

67 Tom Levitt. May 2019. "EU ignoring climate crisis with livestock farm subsidies, campaigners warn." *The Guardian*. https://www.theguardian.com/environment/2019/may/22/eu-ignoring-climate-crisis-with-livestock-farm-subsidies-campaigners-warn

68 David Cody et al. 2017. How Large Are Global Fossil Fuel Subsidies? World Development. 91: 11-27. https://www.sciencedirect.com/science/article/abs/pii/S0305750X16304867

69 Neela Banerjee, Georgina Gustin, John H. Cushman Jr. December 21, 2018. The Farm Bureau: Big Oil's Unnoticed Ally Fighting Climate Science and Policy. *Inside Climate News*. https://insideclimatenews.org/news/20122018/american-farm-bureau-fossil-fuel-nexus-climate-change-denial-science-agriculture-carbon-policy-opposition

70 World Meteorological Organization. February 6, 2019. "WMO confirm past 4 years were the warmest on record." WMO News . https://public.wmo.int/en/media/press-release/wmo-confirms-past-4-years-were-warmest-record

71 U.S. Department of Agriculture, Farm Service Agency. August 12, 2019. Farmers Prevented from Planting Crops on More than 19 Million Acres. News Release. https://www.fsa.usda.gov/news-room/news-releases/2019/report-farmers-prevented-from-planting-crops-on-more-than-19-million-acres

72 Fred Yoder. October 30, 2019. Testimony of Fred Yoder for "Solving the Climate Crisis: Opportunities in Agriculture" Hearing, United States House of Representative Select Committee on the Climate Crisis. https://docs.house.gov/meetings/CN/CN00/20191030/110162/HHRG-116-CN00-Wstate-YoderF-20191030.pdf

73 Fred Yoder. October 30, 2019. Testimony of Fred Yoder for "Solving the Climate Crisis: Opportunities in Agriculture" Hearing, United States House of Representative Select Committee on the Climate Crisis. https://docs.house.gov/meetings/CN/CN00/20191030/110162/HHRG-116-CN00-Wstate-YoderF-20191030.pdf

74 Solutions from the Land: What is SFL? https://www.sfldialogue.net/what_is_sfl.html

75 Daniel Bigelow. 2017. A Primer on Land Use in the United Sates. Amber Waves. United States Department of Agriculture, Economic Research Service. https://www.ers.usda.gov/amber-waves/2017/december/a-primer-on-land-use-in-the-united-states/

76 National Sustainable Agriculture Coalition. 2019. *Agriculture and Climate Change: Policy Imperatives and Opportunities to Help Producers Meet the Challenge*. https://sustainableagriculture.net/wp-content/uploads/2019/11/NSAC-Climate-Change-Policy-Position_paper-112019_WEB.pdf

77 *The Lancet*. 2019. The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. https://www.thelancet.com/commissions/global-syndemic

78 Global Panel on Agriculture and Food Systems for Nutrition. 2016. Foresight Report on Food Systems and Diets: Facing the Challenges of the Twenty-first Century. London, UK. https://glopan.org/sites/default/files/ForesightReport.pdf