FARMING FOR THE FUTURE:

Organic and Agroecological Solutions to Feed the World

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Friends of the Earth

SOURCE: creative commons

Buffer strips planted in permanent vegetation can help to manage soil and water quality and provide habitat for beneficial organisms; planting along contour lines can reduce soil erosion.

Acknowledgements

This report was written by Christopher D. Cook, Kari Hamerschlag, Friends of the Earth U.S. and Kendra Klein, PhD, Friends of the Earth U.S. with contributions from Friends of the Earth International and Friends of the Earth Europe. We are grateful for the extensive research and editorial support provided by Maria Deloso.

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About Friends of the Earth

Friends of the Earth U.S., founded by David Brower in 1969, is the U.S. voice of the world's largest federation of grassroots environmental groups, with a presence in 75 countries. Friends of the Earth works to defend the environment and champion a more healthy and just world. Through our more than 45-year history, we have provided crucial leadership in campaigns resulting in landmark environmental laws, precedent-setting legal victories and groundbreaking reforms of domestic and international regulatory, corporate and financial institution policies. Our current campaigns focus on promoting clean energy and solutions to climate change, ensuring the food we eat and products we use are safe and sustainable, and protecting marine ecosystems and the people who live and work near them. **www.foe.org**

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Introduction

There is no debate that eliminating hunger worldwide is one of humanity's greatest challenges in the 21st century. However, there are radically divergent visions for how to achieve this goal. Many people equate "feeding the world" with the need to produce more food. Yet this simplistic analysis ignores fundamental facts about world hunger. In fact, the mandate to produce more food to feed the world is often invoked to justify food and farming policies and practices that exacerbate the conditions of hunger and undermine our ability to feed future generations.

Feeding the world sustainably requires that we protect the ecological resources that are essential for producing food now and in the future. As this report documents, four decades of scientific evidence show that agroecological farming, including diversified organic agriculture,† is the most effective agricultural response to the environmental challenges that threaten our future food security, such as climate change, soil erosion, water scarcity and loss of biodiversity.

Feeding the world sustainably requires that we protect the ecological resources that are essential for producing food now and in the future.

Furthermore, research consistently demonstrates that world hunger is not primarily a problem of overall supply of food, but rather of poverty, lack of democracy and unequal access to land, water and other resources, especially for women.[1,2] As a systems-based approach to food and farming, agroecology addresses the social and economic drivers of chronic hunger endured by nearly 800 million people around the world.[3]

Research consistently demonstrates that world hunger is not a problem of supply, but rather of poverty, lack of democracy and unequal access to land, water and other resources.

Meanwhile, today's dominant industrial food system is rapidly depleting and degrading the world's soil, water and biodiversity; intensifying climate disruption; consolidating wealth and power over food-related resources; and accelerating poverty and hunger. Environmental harm caused by industrial agriculture costs the world $3 trillion each year according to the United Nations Food and Agriculture Organization.[4]

Despite this evidence, a chorus of agribusiness leaders, lobbyists and policymakers insists that we need more of the same to feed a growing population of up to nine billion people by 2050. As

† Diversified farming systems are a set of methods and tools developed to produce food sustainably by leveraging ecological diversity at plot, field, and landscape scales. – UC Berkeley Center for Diversified Farming Systems

Friends of the Earth's 2015 report Spinning Food documents, agrichemical companies and their allies spend tens of millions of dollars a year to spread misleading messages about the safety and necessity of chemical-intensive industrial agriculture. This narrative — along with a political process captured by corporate interests — bolsters a system that delivers billions of dollars a year in profits to agribusinesses. This means yet more fossil-fuel-intensive production and costly inputs – including pesticides, synthetic fertilizers, antibiotics, growth hormones and genetically engineered seeds.

This report debunks three dominant myths about food, farming and hunger that keep society on the path of business as usual. We broadly characterize this as the path of "industrial agriculture" and introduce the principles of agroecology as a more sustainable and just foundation for our food future.

We detail extensive research showing that agroecological farming systems are a crucial foundation to feed a growing world population, protect farmer livelihoods and preserve ecological resources to sustain future generations. Our analysis spans both developed and developing countries.

Finally, we discuss policy priorities for advancing agroecological farming, including diversified organic systems. While we focus primarily on the United States, it will take a diversity of approaches and innovations at both local and global scales to transform our food and farming systems.

In the face of climate change and rising demand for resources, the need for ecologically sustainable and resilient food production is more urgent than ever. "Increasing the proportion of agriculture that uses sustainable, organic methods of farming is not a choice, it's a necessity," says Claire Kremen, professor of Conservation Biology at University of California at Berkeley, "We simply can't continue to produce food far into the future without taking care of our soils, water and biodiversity."[5]

"Increasing the proportion of agriculture that uses sustainable, organic methods of farming is not a choice, it's a necessity. We simply can't continue to produce food far into the future without taking care of our soils, water and biodiversity."

— Professor Claire Kremen, UC Berkeley

The good news is that solutions are available — if policymakers, citizens, and businesses are willing to make vitally needed changes. Over the past decade, the ecological farming and food sovereignty movements have grown from a small trickle to a powerful stream, propelling millions of farmers, eaters and policymakers toward a better future. By advancing agroecology and organic farming, Friends of the Earth and our allies are helping to lead a groundswell of citizen, consumer and farmer action focused on building a sustainable, healthy and equitable food system for all.

SOURCE: CEDAR CIRCLE FARM

Diversified, organic crop production at Cedar Circle Farm, Vermont.

I. Farming at the Crossroads: Ecological versus Industrial Agriculture

Agroecology: Building a Healthy, Just and Resilient Food Future

Agroecology — the science and practice of sustainable agriculture — creates highly productive farming systems by tapping farmers' knowledge and integrating agricultural innovations developed over millennia with emerging scientific research.[6] While industrial agriculture is chemically-intensive and biologically-simplified, agroecology works with nature as a powerful ally, adapting to and regenerating nature's resources.[7] Agroecological farming methods include intercropping, cover cropping, crop rotation, conservation tillage, composting, managed livestock grazing and combined animal and plant production.

These methods are the foundation of organic agriculture, a certified set of production standards that are rooted in agroecological principles. The U.S. Department of Agriculture National Organic Program describes organic agriculture as the application of a set of cultural, biological and mechanical practices that support the cycling of on-farm resources, promote ecological balance and conserve biodiversity. Organic farming can be considered a subset of the agroecological farming systems that exist around the world, many which are not certified.

Biological control, like the use of ladybird beetles to consume aphids, relies on natural mechanisms of predation, parasitism and herbivory to control pests.

As this report describes in detail, the research is clear that agroecological farming systems, including organic, can produce ample yields to feed a growing world population while boosting agricultural resilience to climate change and regenerating natural resources.

Agroecological farming can produce ample yields to feed a growing world population while boosting agricultural resilience to climate change and regenerating natural resources.

Ecological farming systems can generate many environmental benefits, including water conservation, decreased soil erosion, reduced use of synthetic chemicals and greater biodiversity in the soil and on the farm. They can also help to mitigate and boost resilience to climate change. They strengthen resilience to drought and floods by improving soil structure and water-holding capacity and can decrease agriculture's unsustainable energy use and greenhouse gas emissions.[8,9,10] By sequestering more carbon in the soil than conventional practices, these methods can be an important part of climate change mitigation strategies.[11,12]

Agroecology is not only about farming practices, it is a holistic approach that includes cultural diversity and social justice as important aims of our food and faming systems. Agroecology is a central pillar of food sovereignty, a global grassroots movement working to combat poverty, inequality and hunger by promoting democratically-controlled food production and challenging corporate power in our food system.[13] The research is clear: world hunger is caused primarily by poverty, lack of democracy and unequal access to land, water and other resources and infrastructure, especially among women.[14,15] Rather than simply producing more food under unequal conditions, the solution to hunger hinges on creating more democratic and fair political and economic systems that expand access to resources. Agroecology challenges unjust power and inequality in society and promotes policies and practices that make farmers, fisherfolk, pastoralists, indigenous people, workers, consumers and citizens the primary decision makers about food and farming.

Expanded U.S. Organic Production Needed to Meet Growing Demand

Agroecology can refer to a wide range of ecologically restorative food and farming systems, including diversified organic production that meets or exceeds the standards of the U.S. National Organic Program. With $39 billion in organic sales in 2014, the U.S. accounts for 43 percent of the global market for organic food,[16,17] yet it accounts for just five percent of land under organic production worldwide.[18] Less than one percent of U.S. cropland is devoted to organic production.[19] Despite a 300 percent increase in certified organic operations in the U.S. since 2002,[20] farmers are not able to keep up with demand.

There is a significant need and opportunity to increase domestic, diversified organic production in the United States.[21] The government's failure to invest adequately in domestic organic agriculture represents a missed opportunity to deliver many benefits to U.S. farmers, food businesses and consumers. Research demonstrates that organic farming systems are more profitable for farmers, reduce consumer and farmworker exposure to pesticides and provide an impressive range of environmental benefits (see table below).[22]

Some have raised concerns that increasing corporate ownership of organic brands and farming operations has begun to mirror the economic consolidation and mono-cropping associated with the industrial food system.[23] Research shows that organic systems that employ diversification techniques like multi-cropping and crop rotations perform better than organic monoculture systems.[24] State and federal research and policies should foster diversified organic production and support the entry of small and mid-scale producers into the market.

Table 1: Environmental Benefits of Organic Agriculture

Organic farming practice	Environmental benefits
Crop rotation	Enhances soil quality, disrupts weed, insect and disease life cycles, sequesters carbon and nitrogen, diversifies production
Manure, compost, green manure use	Enhances soil quality, sequesters carbon and nitrogen, contributes to productivity
Cover cropping	Enhances soil quality, reduces erosion, sequesters carbon and nitrogen, prevents dust (protects air quality), improves soil nutrients, and contributes to productivity
Avoidance of synthetic fertilizers	Avoids contamination of surface and ground waters, enhances soil quality, sequesters carbon, mitigates salinization (in many cases)
Avoidance of synthetic pesticides	Enhances biodiversity, improves air quality, enhances soil quality, assists in effective pest management, prevents harm to pollinators, reduces costs of chemical inputs, and reduces exposure of farmworkers and rural communities to harmful pesticides
Planting habitat corridors, borders, and/or insectaries	Enhances biodiversity, supports biological pest management, provides wildlife habitat
Buffer areas	Improves water quality, enhances biodiversity, prevents wind erosion

Source: *Adapted from Organic Farming for Health and Prosperity. OFRF Executive Summary 2011*

SOURCE: creative commons

Monocultures rely on high inputs of synthetic fertilizer and pesticides to manage fertility, pests and disease.

Industrial Agriculture: Undermining our Future Food Security

Industrial agriculture relies on monocultures, large-scale energy-intensive operations and chemical inputs that are harmful to humans and the planet. This toxic mix includes synthetic pesticides, fertilizers, growth hormones, antibiotics and crops that are genetically engineered to be herbicide tolerant. These factory-like industrial practices are undermining the ecosystems we depend on to grow food; depleting and degrading the world's soil, water and biodiversity; and intensifying climate disruption.[25]

The dominant industrial food system also generates enormous social and public health costs. The political and economic structures underlying the global food system are consolidating wealth and power over food-related resources and accelerating world poverty and hunger.[26] Meanwhile, overconsumption of unhealthy foods in some regions drives rising rates of chronic diseases such as obesity and type 2 diabetes.[27] A growing body of evidence links certain classes of agricultural pesticides to illnesses including cancers, neurodevelopmental disorders, reproductive disorders, asthma, birth defects and acute poisonings.[28,29] These diseases disproportionately impact low income communities and people of color in the U.S. and around the world. Together, the global economic cost of premature death, disability and disease connected to food production and consumption is hundreds of billions of dollars a year.[30,31]

Evidence of industrial agriculture's destructive path is everywhere:

- Rapid depletion and degradation of soil and water resources.[32,33]
- Generation of major greenhouse gas emissions and significant vulnerability to climate change.[34]
- Widespread pesticide and fertilizer pollution of water ways and oceanic "dead zones" linked to fertilizer runoff.[35]
- Large-scale habitat and biodiversity losses threatening essential species, including pollinators.[36,37]
- Rapidly dwindling genetic diversity of seeds, crops and livestock breeds.[38]
- Severe animal suffering.[39]
- Impoverishment of farmers and agricultural workers worldwide.[40,41]
- Reduced effectiveness of antibiotics to fight human diseases.[42,43]
- Nearly 800 million people suffering from hunger, 1.9 billion overweight or obese, and billions spent on diet-related diseases.[44,45]
- Rapid loss and concentration of farmlands and water access due to land grabs and development.[46,47]
- Poverty wages for millions of agricultural and food industry workers who suffer high rates of injury and chronic illness.[48,49]
- Increased obesity and type 2 diabetes epidemics in some countries and pesticide-related diseases suffered disproportionately by farm workers and rural communities worldwide.[50]

"Unveiling the hidden costs of mainstream agriculture. . . [shows] that investing in conversion to sustainable food and agriculture systems is a much cheaper option than current expenditures for environmental mitigation and public health," says Nadia El-Hage Scialabba of the United Nation's Food and Agriculture Organizations (FAO).

II. Countering Food Industry Myths with Facts

In this section we tackle three pervasive misconceptions about the food system. These misleading claims, which are propagated by agribusiness, philanthropic and international institutions and policymakers, are used to justify policies, research and markets that propel destructive agricultural practices and concentrate wealth and power in the hands of the few. The facts illustrate why the current industrial food system is untenable — and why we must continue to build a more sustainable and just food system rooted in agroecological principles.

Addressing the Root Causes of World Hunger

Myth: We must significantly increase food production to feed the world.

Facts: Scientists estimate that farmers already produce enough food to feed 10 billion people — far more than the current population of roughly 7.3 billion.[51] Still, nearly 800 million go hungry every day and many more are undernourished.[52] Research consistently demonstrates that world hunger is not a problem of supply, but rather of poverty, lack of democracy and unequal access to land, water and other resources.[53,54]

Solution: Solving world hunger requires policies and programs that democratize access to food, arable land, water, credit and fair markets, particularly for women. To address hunger and poverty sustainably, we must expand public investment in agroecological farming, especially among the small food producers who make up more than 90 percent of all farmers worldwide.[55] We must also reduce global food waste and shift consumption towards plant-based foods (particularly in the U.S. and other wealthy countries that consume large amounts of meat) and away from growing feed for livestock and biofuels.

Smallholders are the backbone of world food supply; they represent over 90 percent of farmers worldwide and provide more than 80 percent of the food consumed throughout much of the developing world, particularly Southern Asia and sub-Saharan Africa.[56] Fostering small farmers' ability to feed themselves and their communities is fundamental to food security and poverty reduction, especially for more than 1 billion poor, rural people worldwide.[57,58]

The dominant industrial food system is rife with systemic inequalities that exacerbate poverty and hunger. By concentrating food sector profits, market control and access to seeds and land among a handful of corporations, and by generating profits based on poverty wages and low crop prices for farmers, this system impoverishes millions of farmers and workers across the globe.[59] From Africa and Asia to Latin America and the U.S., corporate control over markets and supply chains is displacing millions of small-scale farmers.[60,61] Massive land grabs around the world deprive small farmers — especially women — of land and resources needed to feed their families and build thriving, food-secure communities.[62] These dynamics have created some of the world's highest rates of poverty and hunger among small-scale food producers and rural communities worldwide.[63] Farm laborers and food industry workers across the world suffer poverty wages and high rates of injury and chronic illness.[64,65] In the U.S., consistently low wages make food system workers twice as likely as others to receive federal food assistance.[66]

Making matters worse, much of agricultural production worldwide is not devoted to feeding people. In the U.S., 36 percent of all corn is used to feed livestock, another 40 percent for biofuels.[67] This means vast amounts of farmland that could produce a variety of nutritious foods are locked up in feed and fuel production. These trends are replicated globally: roughly one-third of grain produced worldwide becomes animal feed while 17 percent goes to ethanol and other biofuels.[68] Devoting land and food crops to biofuel production is particularly harmful, as it raises food prices and diverts land and resources away from food production.[69] Finally, approximately one-third of the food that is produced globally (1.3 billion tons) never makes it to the plate because it is lost to waste and spoilage or left in the field.[70]

The Economist summarized the shortcomings of the assumption that world hunger is an issue of supply in a February 2011 special report, stating, "Indeed, the world produces more than just enough to go round. Allowing for all the food that could be eaten but is turned into biofuels, and the staggering amounts wasted on the way, farmers are already producing much more than is required — more than twice the minimum nutritional needs by some measures. If there is a food problem, it does not look like a technical or biological one."[71]

Producing Enough Food to Feed the World

Myth: Organic farming cannot produce enough food to feed the world.

Facts: A growing body of research shows that agroecological farming systems, including organic agriculture, can yield more than enough food to feed a growing population while generating significant economic, health and environmental benefits.[72,73] By improving soil, conserving water and protecting biodiversity, ecological farming methods create greater resilience than industrial agriculture to the impacts of climate change.

Solution: To ensure ample yields while protecting natural resources, we must invest more public funds in agroecological farming research, technical assistance, credit access and other incentives to expand regional, organic and diversified farming systems.

While organic systems, on average, produce lower yields than conventional farming systems, research has found that organic can match or exceed conventional yields depending on the crop, growing conditions and management practices.[74,75,76,77] A UC Berkeley meta-analysis of 115 studies found that yields for organic agriculture are higher than previously thought when farmers use diversification techniques such as multiple cropping and crop rotation. In these cases, the yield gap shrinks to less than 10 percent. For some crops — including legumes, oats, tomatoes and apples — the analysis found no significant yield difference.[78] Research from the U.S. Department of Agriculture (USDA) shows that agroecological grain production using fewer synthetic chemicals can match or exceed U.S. industrial grain yields while providing equal or higher profits to farmers and dramatically reducing freshwater toxicity.[79]

Beyond Yield: The Many Benefits of Organic Farming

When assessing the productivity of farming systems, we must go beyond a narrow focus on yield. While conventional farming systems have achieved higher yields over the past half century, they have too often done so at great expense to human health, workers' rights, animal welfare and the environment. If we take the entire system into account, research shows that organic approaches consistently outperform conventional on a broad set of health and sustainability criteria. According to a recent meta-analysis, organic farming systems are more profitable for farmers, deliver equally or more nutritious food that contains less (or no) pesticide residues and provide multiple ecosystem benefits (see Figure 1, next page).[80]

Organic farming systems consistently outperform conventional systems on a broad set of health and sustainability criteria - they are more profitable for farmers, deliver equally or more nutritious food that contains less (or no) pesticide residues and provide multiple ecosystem benefits.

Protecting and regenerating natural resources ensures our ability to produce ample food for future generations. Well-managed organic systems can reduce soil erosion, protect water resources, produce fewer greenhouse gases, store more carbon in the soil, provide more pollinator habitat and increase the water-holding capacity of soils.[81] By building soils and developing locally-adapted seeds, organic and other agroecological methods can help to protect yields amid the weather extremes and seasonal disruptions of climate change.[82,83]

Organic farming can also provide greater economic benefits to farmers. A meta-analysis of 40 years of studies of 55 crops grown on five continents found that organic agriculture increased farmers' profitability by 22-35 percent over non-organic production.[84] In the U.S., studies show that organic farmers earn a higher net return than do their conventional counterparts due to lower input costs and higher price premiums.[85,86]

Organic and other ecological farming methods can play a particularly important role in developing nations because they improve yield while maintaining or lowering the costs of production. By prioritizing farmer knowledge and innovation over costly inputs like pesticides and genetically engineered seeds, agroecological methods can be more accessible to low-income farmers. According to the United Nations Environment Programme (UNEP), the majority of chronically hungry people in developing countries are small farmers who are often too poor to purchase inputs and are marginalized from markets.[87] A UN report on organic agriculture and food security in Africa found that organic production systems outperformed traditional systems and yielded on

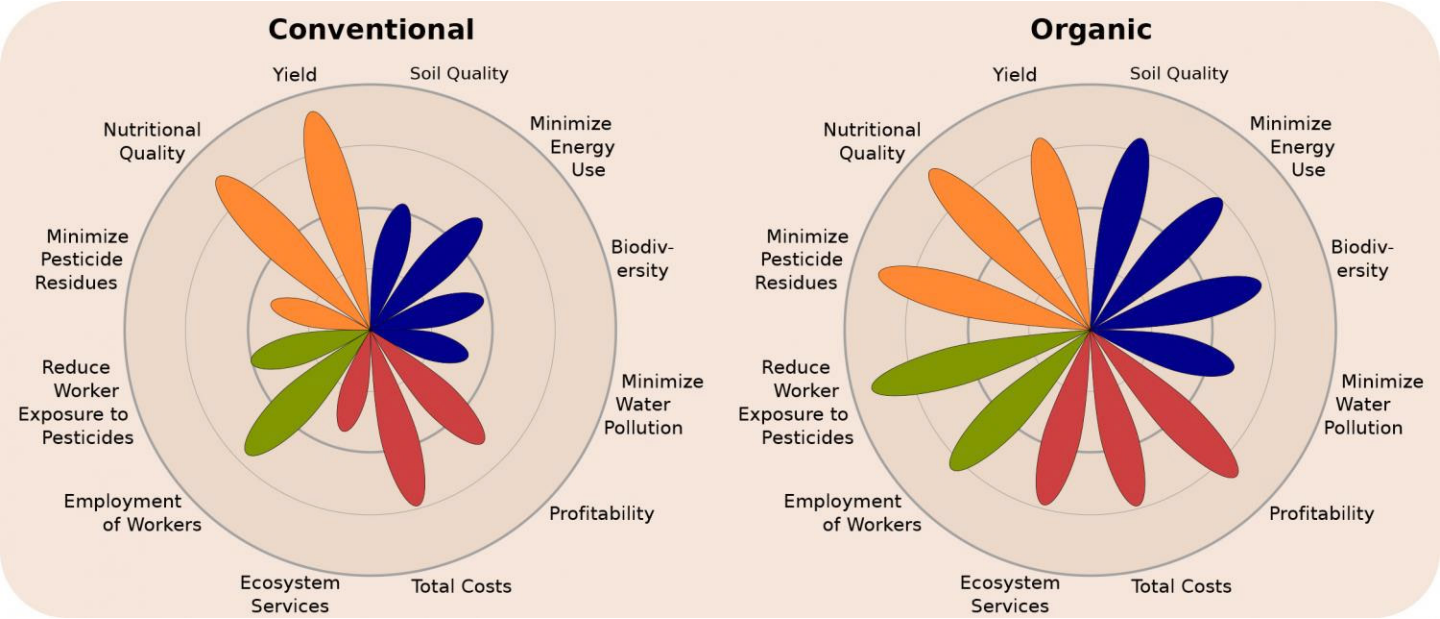

Figure 1. *An assessment of organic farming relative to conventional farming illustrates that organic systems provide better balance in the four areas of sustainability: production (orange), environment (blue), economy (red) and well-being (green). Each petal's length represents the level of performance of specific sustainability metrics. Credit: Reganold. & Wachter (2016). Organic agriculture in the twenty-first century. Source: Nature Plants.*

par with conventional.[88] One meta-analysis found that diversified farming practices can improve yields by 174 percent in developing nations compared to conventional subsistence strategies.[89] The extra labor required for organic agriculture can be a benefit, providing rural employment and development opportunities.[90]

Protecting Human and Ecological Health for Long-Term Sustainability

Myth: Large-scale industrial agriculture is more efficient and sustainable than ecological approaches to farming and provides the technologies and methods we need to feed the world.

Facts: Measured simply by the production of calories and economic efficiency, industrialized agriculture might seem "efficient," but this ignores the massive environmental, social and health degradation wrought by industrial food production, processing, distribution, consumption and waste. By all of these measures — costs we all pay — the dominant food system is remarkably expensive and inefficient. Rather than feeding the world sustainably into the future, the industrial food system is cutting off the branch we're sitting on by degrading the ecosystem functions we rely on to produce food.

Solution: Agroecological farming methods are scientifically proven to be the best path to long-term sustainable food production; they produce ample harvests while protecting human and ecological health. Policymakers must strengthen regulation of industrial agriculture, eliminate subsidies that promote destructive industrial farming practices and invest in diversified, ecological farming systems.

According to a recent report by the UN FAO, environmental damage from conventional agriculture costs the world $3 trillion each year, including $1.8 trillion in costs from livestock production.[91] These expenses include the degradation and depletion of soil and water and loss of biodiversity. The report shows that agroecological methods greatly diminish environmental costs while improving farmer incomes.

Environmental damage from conventional agriculture costs the world $3 trillion each year, including $1.8 trillion in costs from livestock production.

These hidden costs will only increase if current trends in population growth, meat and energy consumption and food waste continue.[92] These impacts are exacerbated by international trade regimes such as the World Trade Organization and trade deals such as the North American Free Trade Agreement (NAFTA) and the Central America Free Trade Agreement (CAFTA).[93] A new wave of mega-trade deals, including the Transatlantic Trade

and Investment Partnership (TTIP) and the Trans Pacific Partnership (TPP), will accelerate the harmful impacts of industrial agriculture by prioritizing industrial production of export commodities while eroding public investments in diversified food production for local and regional consumption.[94,95] These trade regimes promote input-intensive agriculture that pushes farmers into debt, causing farm closures and consolidation, poverty and migration.[96]

Rather than address the structural causes of poverty, hunger and environmental degradation, agribusiness promotes further intensification of the industrial system through costly and ineffective distractions such as "climate-smart agriculture" and "sustainable intensification," in which synthetic chemicals and genetically engineered crops play a central role.[97]

The Empty Promises of Genetically Engineered Crops

Nowhere is the drive for further intensification of industrial agriculture more apparent than the push to expand genetic engineering (GE) as a solution to both world hunger and environmental degradation.

As detailed by the Friends of the Earth report, Spinning Food, the biotech industry has promoted a false narrative of consensus that genetically engineered crops produce higher yields and reduce pesticide use.[98] Contrary to this widely repeated industry myth, after more than 20 years of commercial use, genetically engineered crops have failed to significantly increase yields.[99] While some GE crops have demonstrated modest yield gains (e.g. Bt corn), most yield increases over the past two decades have resulted from conventional breeding and other improvements rather than from genetic engineering.[100]

According to the USDA, more than 90 percent of genetically engineered crops planted in the U.S. are designed to tolerate treatments of herbicides like glyphosate (aka Roundup).[101] Since the advent of Roundup Ready GE crops, use of glyphosate in the U.S. has increased by at least 400 million pounds.[102] As of 2012, the proliferation of glyphosate-resistant "superweeds" affected almost half of all U.S. farmers, damaging yields and triggering increased use of herbicides.[103,104] While agrichemical companies have promoted glyphosate as safe and benign, the World Health Organization recently determined that it is a probable human carcinogen.[105]

Patents and intellectual property rights determine which GE crops become available and who benefits from them. Just four corporations — Monsanto, Dupont, Syngenta and Dow AgroSciences — own 80 percent of the U.S. corn market, 70 percent of the U.S. soy market, and more than half of the world's seed supply.[106,107,108] The vast majority of GE crops on the market have been engineered to express just two traits — Bt (which expresses a protein that acts as a pesticide) and herbicide tolerance — in just four crops: corn, soy, canola and cotton. Far from addressing hunger, these crops are not grown as staple foods, but are used primarily for animal feed, biofuels, fiber or as ingredients in processed foods.[109,110]

The pipeline of GE crops awaiting approval by the USDA promises more of the same — herbicide-tolerance for commodity crops. Experts predict that new GE crops designed to tolerate both 2,4-D and glyphosate herbicides will spur greatly increased use of even more toxic pesticides.[111] Other potentially harmful impacts are only starting to come to light. After approving a new herbicide mixture developed by Dow AgroSciences that uses 2,4-D and glyphosate, the EPA in November 2015 sought to revoke its registration for Dow's new pesticide mixture, called Enlist Duo, because of concerns about synergistic toxicity.[112]

As with other forms of input-intensive agriculture, corporate-controlled GE crop systems exacerbate economic inequalities in farming. They increase farmers' vulnerability to the influence of seed and chemical companies and restrict their ability to experiment, innovate and work cooperatively with their community.[113] From India to the U.S., proprietary seeds and companion herbicides trap farmers in debt and inequitable contracts with powerful global firms.[114]

We cannot afford to expand this toxic industrial system that fails to feed the world when research demonstrates that agroecological alternatives can produce ample food to feed everyone while helping to preserve our health and the environment for future generations.

SOURCE: ©creative commons

More than 90 percent of genetically engineered crops planted in the U.S. are designed to tolerate treatments of herbicides like glyphosate (aka Roundup).

III. Creating a Sustainable and Just Food System to Feed the World — Now and in the Future

Feeding the world sustainably requires that we protect the ecological resources that are essential for producing food now and in the future. Research shows that agroecological practices can improve agricultural resilience to the impacts of climate change, regenerate soil health, protect water resources and foster biodiversity in the soil and on the farm, which improves natural weed and pest management. Ecological farming practices are also a relatively inexpensive way to reduce greenhouse gas emissions and remove CO_2 from the atmosphere by storing carbon in the soil.[115]

Along with sustainable farming practices, agroecology provides guiding social and political principles that promote a democratic transformation of the food system. "Agroecology is political," states the Report of the International Forum for Agroecology from Nyeleni, Mali, "It requires us to challenge and transform structures of power in society."[116]

"Agroecology is political. It requires us to challenge and transform structures of power in society."

—Report of the International Forum for Agroecology, Nyeleni, Mali

Reducing Energy Use and Greenhouse Gas Emissions

Numerous studies show that agroecological farming systems generate far lower greenhouse gas emissions than chemical-based agriculture.[117] Farms using organic methods emit from one-half to two-thirds less carbon dioxide per acre of production than large industrial farms.[118] Unlike conventional operations, organic and diversified farms rely more on people power and less on heavy machinery and use natural methods rather than climate polluting petroleum-based chemicals to build soil fertility and handle pests.[119] Research from the United Kingdom's Department for Environment, Food and Rural Affairs notes that organically-grown crops require less energy per unit area than conventional crops, largely because of lower fertilizer and pesticide inputs.[120,121]

The Climate Solution under Our Feet

One of our greatest assets for combating climate change lies right under our feet. Well-managed soils can serve as an important carbon sink for climate change mitigation.[122] With proper soil management, agriculture could offset about 20 percent of all global annual CO_2 emissions, at least in the short run, according to University of Aberdeen researchers.[123] Organic farming systems boast levels of soil organic matter averaging 4 to 5.5 percent, compared to 3 to 4 percent in conventional farming operations.[124] Every one percent increase of soil organic matter indicates roughly 21 tons of carbon sequestered per hectare.[125] According to the UN FAO, carbon sequestration in soil represents 89 percent of agriculture's emissions mitigation potential.[126]

SOURCE: CEDAR CIRCLE FARM

Cover crops can help manage soil erosion, soil fertility, water, weeds, pests and diseases.

Climate Resilience and Water Conservation

Organic soil-building practices reduce farmers' water demand by improving water capture, infiltration and storage. Increasing soil organic matter by one percent can enhance water storage in the soil by 16,000 gallons per acre-foot.[127] In a 37-year trial, organic plots produced surface soil moisture levels 42 percent higher than their industrial counterparts, Washington State University researchers found.[128] Organic agriculture systems have proven far more productive and resilient than industrial monoculture farming under drought conditions. In a 21-year farm systems trial conducted by the Rodale Institute, organic cornfields yielded one-third more produce than industrial methods in years of drought.[129]

Fostering Biodiversity

Diversified, low-input organic farming systems also provide healthier habitat for bees and other pollinators and can fight pests and invasive weeds effectively and safely without pesticides and other synthetic chemicals. A 2014 Oxford University meta-analysis found that organic farming increased species richness by 30 percent and abundance by 50 percent, producing broad benefits for biodiversity when compared to industrial farming.[130] Another study found organic farms feature up to six times more plant species[131] and about 50 percent more species of pollinators than conventional farms.[132] Organic farming methods can also greatly increase the density and diversity of soil life.

SOURCE: ©creative commons

Organic farming increases species richness and abundance, producing broad benefits for biodiversity.

Reducing Use of Harmful Pesticides

Along with helping to protect pollinators and other beneficial organisms, the dramatically reduced use of pesticides in organic systems results in less soil, air and water pollution and improved health for farmworkers and consumers.[133] Mounting scientific data links agricultural pesticides to a broad range of illnesses, from neurodevelopmental and reproductive disorders to cancers and asthma.[134,135] Agricultural workers and rural communities face a much greater risk of suffering pesticide-related illnesses than any other sector of society; children of farm workers are particularly vulnerable.[136,137,138,139] In contrast, organic farming protects farmers, farmworkers and rural communities from toxic pesticide exposure since most synthetic pesticides are banned in organic production. Pesticides approved for organic production tend to be far less toxic, degrade faster and are typically used as a last resort compared with the massive quantities and higher toxicity levels of chemicals allowed in non-organic production.[140] For consumers, studies show that eating an organic diet reduces exposure to toxic pesticides.[141,142,143]

Finding the Natural Solution: Crop Rotation and Mixed Livestock System Drives Success on an Iowa Farm

For Iowa farmer Tom Frantzen, synthetic pesticides have no place on the 385-acre farm in northeastern Iowa where he grows corn, soybeans, small grains and hay and raises cattle and hogs. Without using any of the chemical herbicides, insecticides and fertilizers that so many large-scale corn and soybean farmers rely on, Frantzen's farm produces higher returns than many of his "conventional" counterparts. His secret to success lies in an integrated, organic approach using crop rotation, building soil health and incorporating animals and their waste into the farm.

One key strategy: Frantzen uses crop rotation to disrupt the growth of troublesome weeds like Palmer amaranth that can choke off crop yields. "We try to create soil conditions that weeds don't do well with," Frantzen explains. "Sometimes we use cover crops, like rye after corn silage, but in general weeds are kept in check from the crop rotation and the diversified biological integrated approach. That fosters a complex underground world in the soil with lots of tiny creatures that eat the weed seed." While many industrial farmers rotate corn with soybeans year after year, Frantzen rotates four or five crops—either corn-soybean-barley-hay-pasture or corn-soybean-barley-hay.

Including forage in the rotation helps to feed Frantzen's cattle while the hogs dine on grain. In turn, composted manure from the livestock fertilizes the cropland. Integrating livestock into the farm's cycle of production and sustainability is crucial, says Frantzen, "The beef cow herd is extraordinarily important. The cows consume hay and pasture 365 days a year, recycling the biomass on the farm and returning the nutrients back to soil. Without that ecological link, we are in a lot of trouble."

The animals also play a critical role in weed control. Besides nourishing the soil with their manure, Frantzen's hogs and Angus cows will happily eat weeds on the farm—converting what is a problem for most farmers into cheap nutritional food for the animals.

Frantzen thrives due to a steady demand and premium prices for his organic products—and he isn't alone. According to the U.S. Department of Agriculture, organic farmers generally do better financially than their conventional farming counterparts, thanks to the lower input costs and higher price premiums.

SOURCE: ©creative commons

Tom Frantzen (left) with son James at his organic grain and livestock farm in Iowa.

SOURCE: creative commons

Agroecological methods, including cover cropping, crop rotations, mulching, composting, and managed livestock grazing help to build healthy, resilient soil.

Decreasing Meat Consumption, Improving Livestock Production

Consuming less meat and dairy is one of the most important changes we can make to protect our ecological and food future. According to Oxford University researchers, transitioning toward more plant-based diets in line with standard dietary guidelines could save up to $31 trillion globally by diminishing environmental damage and reducing healthcare costs, lost work time and premature deaths.[146]

Industrially-produced animal products are among the most resource-intensive foods. The science is clear that less meat production and consumption translates into significant environmental benefits including cleaner water (fewer pesticides, hormones, nitrates and manure toxins); a smaller carbon footprint; significant water savings; and more land available for food production.[144,145]

Consuming less meat and dairy is one of the most important changes we can make to protect our ecological and food future.

Producing animal products more sustainably is also crucial to creating a healthier food system. When managed responsibly, small and mid-scale livestock production (including intensive and holistic grazing systems) can generate important ecological benefits, including carbon sequestration, water savings and reduced dependence on fossil fuels.[147]

In contrast to factory farm monocultures, agroecological principles support the integration of livestock with crop production, using manure to improve soil fertility and animals to control weeds, thus decreasing dependence on fossil-fuel intensive fertilizers and pesticides. On well-managed pastures, animal waste provides vital organic nourishment for soils and crops, producing less methane than manure stored in vats on factory farms.[148] Rotational and holistic grazing systems can also capture and store more water below the ground.[149]

Research shows that intensive grazing systems can support deep-rooted perennial grasses and build topsoil at a remarkable pace.[150] While carbon sequestration potential varies across ecosystems, research shows the U.S. could sequester about 0.8 to 1.0 metric tons of carbon per hectare by improving management practices and shifting commodity crop acres to pasture.[151] Studies show

that some pasture-based systems in the United States produce a smaller carbon footprint than industrial confinement systems.[152,153]

While organic and pasture-raised meat and dairy are healthier and more sustainable, they still require significant resources to produce, especially compared to plant-based proteins. Long-term sustainability in the food system requires that people eat more plants and less meat and dairy. Eating less and better meat will not only improve human health[154] but will provide markets for farmers who develop less intensive, healthier and more ecologically sound mixed livestock production systems.

Bridging Sustainability and Food Sovereignty

Agroecology is central to food sovereignty, a worldwide grassroots movement for democratic control of resources and access to land, fair prices for producers and regional food production. Food sovereignty asserts that the people who produce, distribute and consume food should be the primary drivers of food production and distribution policies — rather than the corporations, neoliberal trade regimes and market institutions that dominate today's global food system.[155]

Food sovereignty is fundamentally different from food security. Nations can meet food security targets without addressing the environmentally destructive and economically exploitative conditions of the dominant food system.[156] In contrast, food sovereignty advances the capacity of indigenous peoples, peasant farmers, fishers, pastoralists and forest dwellers to produce for themselves, their local communities and wider society using sustainable methods.[157]

This rising global movement — backed by more than 300 million small-scale food producers and agri-food workers, as well as consumers, environmentalists and human rights groups — recognizes the potential for agroecological farming systems to create more jobs, return higher profits to farmers and produce diverse nutritious crops that can improve income and health in farming communities.[158] Investing in regional sustainable food systems can be a win-win for small-scale food producers, families and local economies by spurring jobs and economic growth. By producing a variety of foods for local processing and marketing, farmers generate local employment and expand community economic activity, according to the 2008 IAASTD report.[159] Farmers' markets and local food marketing can also provide important economic benefits for farmers and local economies.[160]

SOURCE: creative commons

Smallholders, like this Tanzanian farmer, represent over 90 percent of farmers worldwide and provide more than 80 percent of the food consumed throughout much of the developing world.

IV. Policy Solutions: Tackling Hunger's Root Causes and Protecting Natural Resources

Agroecology provides the tools needed to transform our food and farming future, but we must invest public funds and create policies to make it happen. To reap the benefits of agroecological farming systems, we must expand policies that prioritize sustainable production, farmer livelihoods, responsible and socially just land use and equitable access to food and agricultural resources. Policymakers must democratize decision-making processes; regulate the negative impacts of industrial agriculture; and replace corporate-friendly "free trade" regimes with policies that foster fair markets that benefit farmers, workers, consumers and the environment. This means rejecting corporate, profit-driven carbon market and trading schemes as a means of incentivizing agroecology and soil carbon sequestration.[161,162,163] To create the truly sustainable food system we need, global and U.S. food and agriculture policies must support and incentivize healthy, diversified, local and regional food economies that link small- and mid-sized farms to regional markets.

Funding Research for a Better Food Future

Despite the many proven benefits of ecological farming, there is a massive disparity in research funding for organic in comparison to conventional agriculture. Of the $49 billion invested globally in agricultural research, less than one percent goes to organic farming.[164] In the U.S., less than two percent of public agricultural research funding goes to organic and biologically diversified farming.[165,166] Agroecological farming approaches have achieved high levels of environmental performance and productivity despite minimal funding. Increased research could improve yields and environmental gains beyond already proven success.[167]

Major U.S. Policy Reform Must be on the Menu

Current U.S. agriculture policies expend billions of dollars in subsidies for ecologically destructive industrial production of commodity crops. Between 2009-2012, the Farm Bill spent an average of $11 billion a year to subsidize chemical-dependent industrial production of grain, seed and fiber crops that provide the raw ingredients for animal feed, biofuels and highly processed food.[168] This misguided use of tax dollars is worsening local food security, undermining soil health and biodiversity and impeding the adoption of more diverse and resilient food production. These subsidies disadvantage small-scale farmers in the U.S. and in developing countries. With large-scale farming operations capturing the lion's share of crop insurance and other subsidies, highly capitalized large-scale operators are able to grow even bigger — further deepening inequities and concentration in the agriculture sector.[169] These subsidies also drive up land costs, making it harder for small and mid-scale farmers to compete.

Meanwhile, U.S. policymakers invest minimal public resources — averaging just $138 million a year from 2009-2012 — to build healthy, diversified, local and regional food economies that link small- and mid-sized farms directly to local and regional markets.[170] These include farmers' markets, community-supported agriculture (CSA) and local garden projects, as well as value-added agricultural enterprises, farm-to-school and other initiatives that make fresh food more accessible and create new markets for local farmers. While USDA spending on organic increased to $167.5 million in 2014, this is still far short of what's needed for research, education, infrastructure and technical assistance to meet the growing demand for organic food in the U.S.[171]

Although the 2014 U.S. Farm Bill delivered modest funding increases for programs that expand local and regional diversified and organic food systems, these funds pale in comparison to the individual subsidies provided to large-scale and often ecologically-destructive farms. Policy solutions in the U.S. require transforming the Farm Bill by shifting away from subsidies for large-scale, chemical-intensive monoculture and towards far greater support for organic agriculture, conservation practices and diversified farming for local and regional markets. Instead of investing billions of dollars in monocultures that don't nourish communities or the environment, policymakers must redirect funds to incentivize agroecological systems,

including diversified organic and sustainable livestock production — a far more effective approach to improving rural economies, food security, environmental sustainability and human health.

To this end, we must:

- Boost public investment in conservation programs, research, technical assistance and other support to expand organic and diversified agroecological systems focused on domestic production;
- Increase small- and mid-scale food producers' access to arable land, water, credit and fair markets with a focus on women, disadvantaged and young farmers;
- Eliminate subsidies that promote destructive industrial farming of crops and livestock and link crop insurance to core conservation practices;
- Shift our diets and enact nutrition, agriculture and procurement policies that promote consumption of more plant-based foods and less meat;
- Shift policies and production away from biofuels and livestock feed and into diversified, nutritious crops;
- Create stricter regulations and anti-trust enforcement to prevent unfair pricing and consolidation throughout the food supply chain;
- Increase living wages and strengthen and enforce labor laws protecting agricultural workers, particularly women;
- Strengthen the regulation of industrial agriculture and concentrated animal feeding operations to reduce air and water pollution and curb the unnecessary use of inputs including pesticides, synthetic fertilizers, antibiotics and hormones; and
- Reduce the billions of tons of food wasted each year.

V. Conclusion

In the face of today's monumental food and agriculture challenges, the solutions are within our grasp. Using well-proven practices that build economic equity, restore our environment and create a resilient and reliable food supply, agroecology offers humanity essential tools to address our biggest crises. Our solutions to climate change, environmental destruction and world hunger must focus on reviving rural economies and advancing food sovereignty, democratizing governance and power in the food economy and raising incomes for small and mid-scale producers, especially women. To feed the world while also confronting climate change, we need policies, incentives and public investments that promote agroecology, diversified organic farming and small- and mid-scale farmer livelihoods. By transitioning from industrial to agroecological food and farming systems, we can produce enough food to feed the world, reduce poverty and restore essential natural resources to feed the planet for generations to come.

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