CAN WE FEED THE WORLD AND SUSTAIN THE PLANET?

A five-step global plan could double food production by 2050 while greatly reducing environmental damage

By Jonathan A. Foley

Right now about one billion people suffer from chronic hunger. The world's farmers grow enough food to feed them, but it is not properly distributed and, even if it were, many cannot afford it, because prices are escalating. But another challenge looms. By 2050 the world's population will increase by two billion or three billion, which will likely double the demand for food, according to several studies. Demand will also rise because many more people will have higher incomes, which means they will eat more, especially meat. Increasing use of cropland for biofuels will put additional demands on our farms. So even if we solve today's problems of poverty and access—a daunting task—we will also have to produce twice as much to guarantee adequate supply worldwide. And that's not all.
By clearing tropical forests, farming marginal lands, and intensifying industrial farming in sensitive landscapes and watersheds, humankind has made agriculture the planet’s dominant environmental threat. Agriculture already consumes a large percentage of the earth’s land surface and is destroying habitat, using up freshwater, polluting rivers and oceans, and emitting greenhouse gases more extensively than almost any other human activity. To guarantee the globe’s long-term health, we must dramatically reduce agriculture’s adverse impacts.

The world’s food system faces three incredible, intertwined challenges. It must guarantee that all seven billion people alive today are adequately fed; it must double food production in the next 40 years; and it must become truly environmentally sustainable—all at the same time.

Could these simultaneous goals possibly be met? An international team of experts, which I coordinated, has settled on five steps that, if pursued together, could increase by more than 100 percent the food available for human consumption globally while substantially reducing greenhouse gas emissions, biodiversity losses, water use and water pollution. Tackling the triple challenge will be one of the most important tests humanity has ever faced. It is fair to say that our response will determine the fate of our civilization.

BUMPING UP AGAINST BARRIERS

At first blush, the way to feed more people seems clear: grow more food, by expanding farmland and improving yield (crops harvested per hectare). Unfortunately, the world is running into significant barriers on both counts.

Society already uses about 37 percent of the earth’s land surface, not counting Greenland or Antarctica, for farms or pastures. Agriculture is by far the biggest human use of land on the planet; nothing else comes close. And most of that 37 percent covers the best farmland. Much of the remainder is covered by deserts, mountains, tundra, ice, cities, parks and other unsuitable growing areas. The few remaining frontiers are mainly in tropical forests and savannas, which are vital to the stability of the globe, especially as stores of carbon and biodiversity. Expanding into those areas is not a good idea, yet five million to 10 million hectares of cropland have been created in each of the past 20 years, with a significant portion of that land conversion happening in the tropics. These additions enlarged the net area of cultivated land by only 3 percent, however, because of farmland losses caused by urban development and other forces, particularly in temperate zones.

Improving yield also sounds enticing.

TO GUARantee THE GLOBE’S LONG-TERM HEALTH, WE MUST DRAMATICALLY REDUCE AGRICULTURE’S ADVERSE IMPACTS.

Yet our research team found that average global crop yield increased by just 20 percent from 1985 to 2005—far less than had been reported. Cereals yield has been rising at less than 2 percent a year since 2000 and yields of pulses (beans, lentils) and root crops by less than 1 percent—rates that are nowhere near enough to double food production by midcentury.

Feeding more people would be easier if all the food we grew went into human hands. But only 60 percent of the world’s crops are meant for people: mostly grains, followed by pulses, oil plants, vegetables and fruits. Another 35 percent is used for animal feed, and the final 5 percent goes to biofuels and other industrial products. Meat is the biggest issue here. Even with the most efficient meat and dairy systems, feeding crops to animals reduces the world’s potential food supply. Grain-fed cattle operations typically use at least 100 kilograms of grain to make one kilogram of edible, boneless beef protein [see “The Greenhouse Hamburger,” on page 108].

Another deterrent to growing more food is damage to the environment, which is already extensive. Only our use of energy, with its profound impacts on climate and ocean acidification, rivals the sheer magnitude of agriculture’s environmental footprint. Our research team has estimated that by 2010 agriculture had already cleared or radically transformed 70 percent of the world’s prehistoric grasslands, 50 percent of the savannas, 45 percent of the temperate deciduous forests and 25 percent of the tropical forests. Since the last ice age, nothing has disrupted ecosystems more. Agriculture’s physical footprint is nearly 60 times that of the world’s pavements and buildings.

Freshwater is another casualty. Humans use an astounding 4,000 cubic kilometers of water per year, mostly withdrawn from rivers and aquifers. Irrigation accounts for 70 percent of the draw. If we count only consumptive water use—water that is used and not returned to the watershed—irrigation climbs to 80 or 90 percent of the total. As a result, many large rivers, such as the Colorado, have diminished flows, some have dried up altogether, and many places have rapidly declining water tables, including regions of the U.S. and India.

Water is not only disappearing, it is being contaminated. Fertilizers, herbicides and pesticides are being spread at incredible levels and are found in nearly every ecosystem. The flows of phosphorus and nitrogen through the environment have more than doubled since 1960, causing widespread water pollution and enor-
mous hypoxic “dead zones” at the mouths of many of the world’s major rivers. Ironically, fertilizer runoff from farmland—in the name of growing more food—compromises another crucial source of nutrition: coastal fishing grounds. Fertilizer certainly has been a key ingredient of the green revolution that has helped feed the world, but when nearly half the fertilizer we apply runs off rather than nourishes crops, we clearly can do better.

Farming also accounts for 10 to 12 percent of the warming effects of greenhouse gases released by human activity—a contribution equal to that of all the road vehicles on the planet. Most of the direct emissions from farming come from methane produced by animals and rice paddies and from nitrous oxide released by over-fertilized soils. Add in the effects of tropical deforestation and other land clearing, and agriculture’s share of global emissions rises to 24 percent of the total.

**FIVE SOLUTIONS**

Modern agriculture has been an incredibly positive force in the world, but we can no longer ignore its dwindling ability to expand or the mounting environmental harm it imposes. Previous approaches to solving food issues were often at odds with environmental imperatives. We could boost food production by clearing more land or using more water and chemicals but only at a cost to forests, streams and wetlands. Or we could restore ecosystems by taking farmland out of cultivation but only by reducing food production. This either-or approach is no longer acceptable. We need truly integrated solutions.

After months of research and deliberation—based on analysis of newly generated global agricultural and environmental data—our international team settled on a five-point plan that deals with food and environmental challenges together.

**Stop expanding agriculture’s footprint.** Our first recommendation is to slow and ultimately stop the expansion of agriculture, particularly into tropical forests and savannas. The demise of these ecosystems has far-reaching impacts on the environment, especially through lost biodiversity and increased carbon dioxide emissions (from clearing land).

Slowing deforestation would dramatically reduce environmental damage while imposing only minor constraints on global food production. The resulting dip in farm capacity could be offset by reducing the displacement of more productive croplands by urbanization, degradation and abandonment.

Many proposals have been made to reduce deforestation. One of the most promising has been the Reducing Emissions from Deforestation and Degradation (REDD) mechanism. Under REDD, rich nations pay tropical nations to protect their rain forests, in exchange for carbon credits. Other mechanisms include developing certification standards for agricultural products so that supply chains can be assured that crops were not grown on lands created by deforestation. Also, better biofuel policy—one that relies on nonfood crops such as switchgrass instead of food crops—could make vital farmland newly available.

**Close the world’s yield gaps.** To double global food production without expanding agriculture's footprint, we must signifi-
Our research group analyzed global patterns of crop yields and found significant yield gaps in many regions: most notably parts of Africa, Central America and eastern Europe. In these regions, better seeds, more effective fertilizer application and more efficient irrigation could produce much more food without increasing the amount of land under cultivation. Our analysis suggests that closing the yield gap for the world’s top 16 crops could increase total food production by 50 to 60 percent, without causing much additional environmental damage.

Reducing yield gaps in the least productive agricultural lands may often require the use of additional chemicals and water. Farmers will have to irrigate and fertilize in responsible ways. They can also make use of other yield-lifting techniques, such as reduced tillage, which disturbs less soil and thus minimizes erosion. Cover crops planted between crop seasons suppress weeds and add nutrients and nitrogen to the soil when plowed under. Lessons from organic and agroecological systems can also be adopted, such as leaving crop residues on fields so that they decompose into nutrients. To close the world’s yield gaps, we also have to overcome serious economic and social challenges, including better distribution of fertilizer and seed varieties to farms in impoverished regions and improved access to global markets for many regions.

Use resources much more efficiently.

To reduce the environmental impacts of agriculture, low- and high-yield regions alike must practice agriculture in ways that produce vastly greater output of crops per unit input of water, fertilizer and energy.

On average, it takes about one liter of irrigation water to grow one calorie of food. Some places use much more, however. Our analysis found that farms can significantly curb water use without much reduction in food production, especially in dry climates. Primary strategies include drip irrigation (where water is applied directly to the plant’s base and not wastefully sprayed into the air); mulching (covering the soil with organic matter to retain moisture); and reducing water lost from irrigation systems (by lessening evaporation from canals and reservoirs).

With fertilizers, we face a kind of Goldilocks problem. Some places have too few nutrients and therefore poor crop production, whereas others have too much, leading to pollution. Almost no one uses fertilizers “just right.” Amazingly, only 10 percent of the world’s cropland generates 30 to 40 percent of agriculture’s fertilizer pollution. Our analysis identified hotspots on the planet—particularly in the central U.S., China, northern India and western Europe—where farmers could substantially reduce fertilizer use with little or no impact on food production.

Among the actions that can fix wasteful overfertilization are policy and economic incentives, such as payments to farmers for: promoting watershed stewardship and protection, reducing excessive fertilizer use, improving manure management (especially manure storage, so that less runs off into the watershed during a storm), capturing excess nutrients through recycling, and instituting other conservation practices. In addition, wetlands could be restored to enhance their capacity to act as natural sponges that filter out nutrients in runoff.

Here again, reduced tillage can help nourish the soil, as can precision agriculture (applying fertilizer and water only when and where they are needed and most effective) and organic farming techniques.
Shift diets away from meat. We can dramatically increase global food availability and environmental sustainability by using more of our crops to feed people directly and less to fatten livestock.

Globally, humans could net up to three quadrillion additional calories every year—a 30 percent increase from our current supply—by switching to all-plant diets. Naturally, our current diets and uses of crops have many economic and social benefits, and our preferences are unlikely to change completely. Still, even small shifts in diet, say, from grain-fed beef to poultry, pork or pasture-fed beef, can pay off handsomely.

Reduce food waste. A final, obvious but often neglected recommendation is to reduce waste in the food system. Roughly 30 percent of the food produced on the planet is discarded, lost, spoiled or consumed by pests.

In rich countries, much of the waste takes place at the consumer end of the system, in restaurants and trash cans. Simple changes in our daily consumption patterns—reducing oversize portions, the food thrown in the garbage, and the number of takeout and restaurant meals—could significantly trim losses, as well as our expanding waistlines. In poorer countries, the losses are similar in size but occur at the producer end, in the form of failed crops, stockpiles ruined by pests or spoilage, or food that is never delivered because of bad infrastructure and markets. Improved storage, refrigeration and distribution systems can cut waste appreciably. Moreover, better market tools can connect people who have crops to those who need them, such as cell-phone systems in Africa that link suppliers, traders and purchasers.

Although completely eliminating waste from farm to fork is not realistic, even small steps would be extremely beneficial. Targeted efforts—especially reducing waste of the most resource-intensive foods such as meat and dairy—could make a big difference.

FEEDING NINE BILLION PEOPLE IN A TRULY SUSTAINABLE WAY WILL BE ONE OF THE GREATEST CHALLENGES OUR CIVILIZATION HAS HAD TO CONFRONT.

MOVING TOWARD A NETWORKED FOOD SYSTEM

In principle, our five-point strategy can address many food security and environmental challenges. If they were done together, the steps could increase the world’s food availability by 100 to 180 percent while significantly lowering greenhouse gas emissions, biodiversity losses, water use and water pollution.

It is important to emphasize that all five points (and perhaps more) must be pursued simultaneously. No single strategy is sufficient to solve all our problems. Think silver buckshot, not a silver bullet. We have tremendous successes from the green revolution and industrial-scale agriculture to build on, along with innovations in organic farming and local food systems. Let’s take the best ideas and incorporate them into a new approach—a sustainable food system that focuses on nutritional, social and environmental performance, to bring responsible food production to scale.

We can configure this next-generation system as a network of local agricultural systems that are sensitive to nearby climate, water resources, ecosystems and culture and that are connected through efficient means of global trade and transport. Such a system could be resilient and pay farmers a living wage.

One device that would help foster this new food system would be the equivalent of the Leadership in Energy and Environmental Design program now in place for constructing new commercial buildings sustainably. This LEED program awards increasingly higher levels of certification based on points that are accumulated by incorporating any of a wide range of green options, from solar power and efficient lighting to recycled building materials and low construction waste.

For sustainable agriculture, foods would be awarded points based on how well they deliver nutrition, food security and other public benefits, minus their environmental and social costs. This certification would help us get beyond current food labels such as “local” and “organic,” which really do not tell us much about what we are eating. Instead we can look at the whole performance of our food—across nutritional, social and environmental dimensions—and weigh the costs and benefits of different farming approaches.

Imagine the possibilities: sustainable citrus and coffee from the tropics, connected to sustainable cereals from the temperate zone, supplemented by locally grown greens and root vegetables, all grown under transparent, performance-based standards. Use your smartphone and the latest sustainable food app, and you will learn where your food came from, who grew it, how it was grown, and how it ranks against various social, nutritional and environmental criteria. And when you find food that works, you can tweet about it to your social network of farmers and foodies.

The principles and practices of our different agricultural systems—from large-scale commercial to local and organic—provide the foundation for grappling with the world’s food security and environmental needs. Feeding nine billion people in a truly sustainable way will be one of the greatest challenges our civilization has had to confront. It will require the imagination, determination and hard work of countless people from all over the world. There is no time to lose.

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