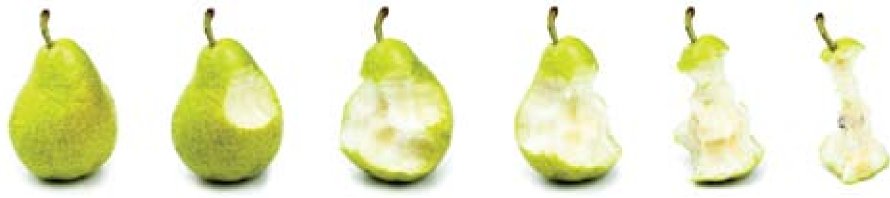
THE PROBLEM OF WHAT TO EAT

At first glance, it doesn't seem that tough a question. Organic farming and eating locally make intuitive sense. Yet does conventional wisdom about eating sustainably hold up to the science? It turns out that many core issues such as pesticide use, soil health, and the impact of food miles are more nuanced and complicated than you might think.

Illustration by JayMontgomery.com

Does Buying Local Reduce Your Carbon Footprint?



There is a growing legion of eaters who describe themselves as "locavores," people who eat only food grown within 100 miles of where they live. Until recently, it was no more than a subculture on the food fringe in San Francisco—an area conveniently within easy reach of a wide range of seasonal produce. But now eating local has gone mainstream. Even Marks & Spencer (the iconic British retailer) has recently announced plans to track and label foods for food mile–conscious shoppers.

But does eating locally really have a lower carbon footprint than eating food transported halfway round the world? Surprisingly, there's scant science to lean on. True, when it comes to air-freight, many local foods do have a lower carbon footprint. But when food arrives by sea, by road, or by rail—as most foods still do—the case is far from clear.

That's the conclusion of one of the most comprehensive reports to date: a 2006 study commissioned by the U.K.'s Department for Environment, Food, and Rural Affairs (DEFRA) (1). One of the study's authors, Ken Green from Manchester Business School, explains that the reason for such a counterintuitive result is that the environmental impact of growing foods far from their point of sale can be low enough that it outweighs the negative impact of transporting foods long distance. It all depends on the efficiency of farming practice and local conditions.

Take the carbon footprint of your morning glass of orange juice. One 2003 study (2) looked at the energy requirements of orange juice produced on a large scale in Brazil, and shipped as concentrate to Europe, versus apple juice processed on a small scale in Europe. A local juice-squeezer driving his car only 10 kilometers each way to sell 100 liters of fruit juice carries an energy burden equivalent to that needed to send fruit concentrate from factory operations in Brazil to Germany.

The authors of the Brazilian orange juice study say that, in the same way that production costs are lowered when larger numbers of items are produced, so also are energy costs. According to researchers at Lincoln University in New Zealand (3), even producing goods such as dairy products, lamb, apples, and onions shipped by sea around the world from New Zealand, where farming and processing are much less energy-intensive, can require less energy than producing them in Britain.

In some ways it shouldn't be a surprise that a shift away from a supermarket-based food system with its central distribution depots, lean supply chains, and big, full trucks may increase the number of food-vehicle miles traveled. A mile traveled by a truck full of groceries is not the same as a farmer driving his small batch of locally-produced juice to a farmers' market.

It's a similar story for a shopper driving to the store in an SUV to pick up a quart of milk. That key part of the equation was missing from most of the studies included the DEFRA report. Most research on food miles ends at the farm gate. But what happens from farm to fork? My actions as a shopper may represent a major part of the energy costs of the food I eat.

Consider the humble potato in my shopping basket. A whopping 45 percent of its energy demand throughout its life cycle (until the point when I eat it) comes from the journey to my house and from how I cook it when I get there.

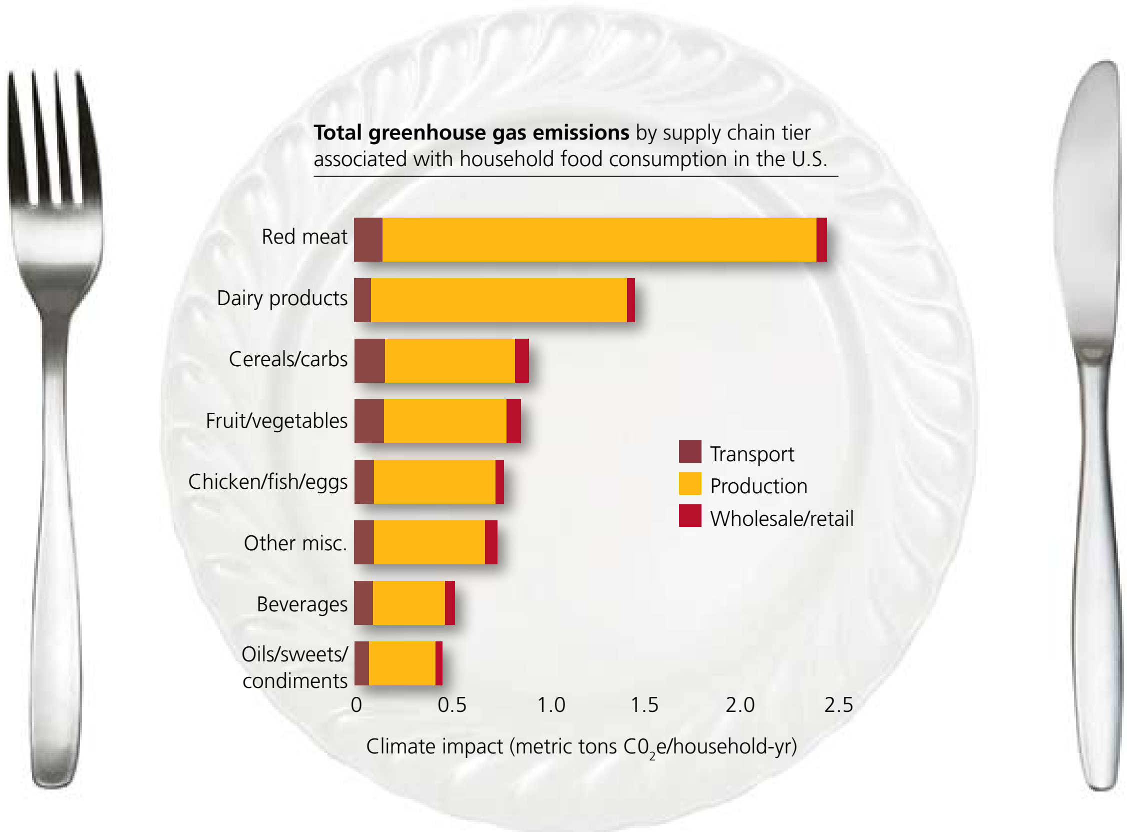
So unless eating local means digging up veggies from my back garden or living next to a farm, I'm not counting on it to reduce my carbon footprint. ❧

—Natasha Loder

1. Foster, C. et al. 2006. Environmental impacts of food production and consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. DEFRA, London, U.K.

2. Schlich, E. and U. Fleissner. June 2003. Comparison of regional energy turnover with global food. LCA Case Studies, pp. 1–6.

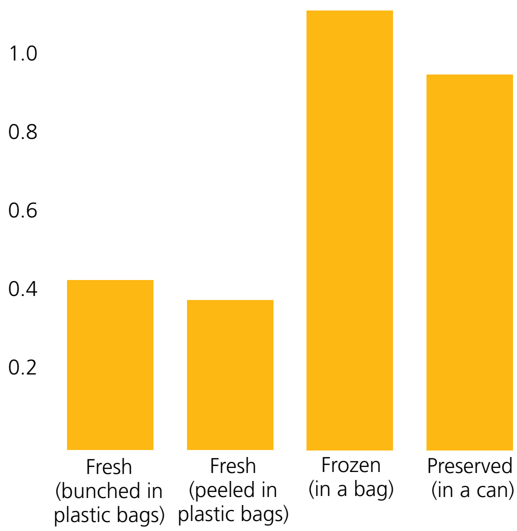
3. Saunders, C., A. Barber & G. Taylor. July 2006. Food miles—Comparative energy/emissions performance of New Zealand's agriculture industry. Lincoln University Research Report No. 285.



NO MEAT TODAY. According to a recent study by researchers at Carnegie Mellon University, foregoing red meat and dairy just one day a week achieves more greenhouse gas reductions than eating an entire week's worth of locally sourced foods. That's because the carbon footprint of food miles is dwarfed by that of food production. In fact, 83 percent of the average U.S. household's carbon footprint for food consumption comes from production; transportation represents only 11 percent; wholesaling and retailing account for 5 percent. **Source**: Weber, C.L. and Matthews, H.S. 2008. Food-miles and the relative climate impacts of food choices in the United States. *Environmental Science & Technology* 42(10):3508–3513.

FOOD COSTS. In 2006, the U.K. Department of Environment, Food and Rural Affairs commisioned a team of researchers at Manchester Business School to compile the most comprehensive evidence to date on the environmental impacts of food (1). For example, one of the studies in the report focused on the global warming potential of carrots produced in western Europe (2). Another found that, although organic milk production in England requires less energy than conventional milk production, it uses much more land (3). Organic dairy farms don't use synthetic pesticides but they emit higher levels of greenhouse gases (e.g., methane and nitrous oxides), acid gases, and eutrophying substances per unit of milk produced. For more information on the impact of other foods, see www.defra.gov.

Global warming potential* of **carrots** (kg CO_2 equivalent per 600 g serving)



Environmental burdens of **conventional and organic milk** production (per liter of milk at the farm gate)

	Conventional	Organic
Energy (in megajoules)	2.5	1.6
Global warming potential* (in grams of carbon dioxide equivalents over 100 years)	1,060	1,230
Eutrophication potential (in grams of phosphate equivalents)	6.3	10.3
Acidification potential (in grams of sulphur dioxide equivalents)	16.2	26.4
Land use (in hectares)	0.0001	0.002

*Global warming potential (GWP) is how much a given mass of greenhouse gas is estimated to contribute to global warming over a given time frame.

Sources: 1. Foster, C. et al. 2006. Environmental impacts of food production and consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. DEFRA, London **2.** Ligthart, T.N., Ansems, A.M.M. & Jetten, J. 2006. Eco-efficiency and nutritional aspects of different product-packaging systems: An integrated approach towards sustainability. TNO consultancy report B&O-A R 2005/232-2 www.tno.nl **3.** Williams, A.G., Audsley, E. & Sandars, D.L. 2006. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. DEFRA Research Project IS0205. Cranfield University and DEFRA www.cranfield.ac.uk.

Is It Time to Replace the Plow?

Australian farmers are among the most innovative in the world, growing their crops in difficult conditions on ancient, infertile soils that have an unfortunate tendency to blow away in clouds of dust. One high-tech solution is known as no-till farming. The plow may be the icon of farming, but it turns out that plowing actually wrecks the soil.

The soil farmers prize has a structure resembling a stack of peas with pores running through it. Earthworms and other creatures maintain this structure, and the whole thing is meshed together by the tendrils of fungi and plant roots—in other words, a spongy soil that holds onto water and won't blow away. Too much tillage destroys that structure.

Tillage is used to bury the previous year's crop residue and destroy weeds. But in no-till farming, herbicide removes the weeds and the new seed is sown directly into the stubble of the last crop. Leaving the stubble in the soil means the planet benefits. Richard Roush, an entomologist at the University of Melbourne, estimates that all that carbon kept in the ground by no-till farming reduces carbon dioxide emissions by up to eight million metric tons per year.

No-till systems also win hands-down when it comes to hanging on to soils. An 11-year farming experiment by the U.S. Department of Agriculture in Beltsville, Maryland, compared crops grown in three ways: conventional tillage, organic methods, or no-till. Compared to the conventionally tilled plot, the organic plot was likely to hang on to 30 percent more soil. But compared to the organic plot, the no-till plot hung on to 80 percent more soil. It's possible to combine organic and no-till on a small scale by relying on hand weeding. But that's not practical for large-scale farming. And without tilling, it's difficult to work manures into the soil.

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The downside to no-till farming is that steel ends up being replaced with chemicals: herbicides control the weeds. But in areas where soil erosion is a major problem, that is probably a fair trade-off, especially bearing in mind that most chemicals do their damage when they piggyback into waterways on the back of eroded soils. David Pimentel is a Cornell University entomologist who has written much about the negative environmental impacts of pesticides. Nevertheless, "I'd take chemicals over soil erosion any day," he says. ❧

—Elizabeth Finkel

Is It Realistic to Give Up Nitrogen Fertilizer?

A 2007 study published in the journal *Renewable Agriculture and Food Systems* (1) provided new data to suggest that organic agriculture can feed the world. The study's authors, led by Catherine Badgely from the University of Michigan, assume the major stumbling blocks to organic farming are low crop yields and insufficient quantities of approved organic fertilizers. However, I have lived and worked in Bangladesh as a Cornell University professor researching agriculture and development for the last 25 years, and I believe that even if these problems could be surmounted, using organic farming to feed the developing world remains a pipe dream.

Most supporters of the idea assume that organic manures are cheap and available to all—even the poor. But this isn't often the case. I see cow dung as a valuable commodity in Bangladesh and elsewhere throughout South Asia. During my walks in the villages, I see it collected—largely by women and children—and used as fuel. It's found in nearly every house, dried and formed into patties to be sold or burned for cooking.

Straw is another organic source of nutrients, but that's not always available either. Rice and wheat straw are collected from the fields and used for cattle feed or thatching for roofs. Even the stubble is used, which the poorest cut for fuel.

Badgely and her coauthors rightly assume that organic manures can supply sufficient nutrients for plant growth. However, the quantities required to sustain such productive growth make it very difficult for the poor to handle. Organics—whether farmyard manure, compost, or cow dung—contain moisture and thus are heavy and difficult to carry from the homestead to the fields.

For example, to raise a six–metric ton rice crop in the peak season requires 100 kilograms of nitrogen. Because of monsoons and the fact

Photo by Craig Meisner

Above: a farmer from Rajshahi western Bangladesh carrying 20 kg of urea fertilizer out to the rice field—a nitrogen equivalent to one ton of good compost.

that several meters of rainfall drains through the soil every three months, it carries a low amount of nitrogen. Assuming we used good-quality manure, it would contain about 0.6 percent nitrogen and thus require 17 metric tons per hectare to produce a six metric ton rice yield.

Can you imagine carrying 17 metric tons of manure, in repeated 50-kilogram loads, in a basket on your head? The lack of machinery and the labor required to apply it compound the challenge.

Plus, there simply isn't enough manure or even plant biomass available to apply 17 metric tons per hectare for even a single annual rice crop across the whole of Bangladesh. Considering there are actually two rice crops a year, the full scale of the problem becomes apparent.

In answer to some of these problems, Badgely and her coauthors propose the use of a leguminous green manure crop. These pulse crops fix nitrogen into the soil from the air through a symbiotic relationship with bacteria in their roots. They provide enough nitrogen for their own growth and, when plowed under, for a subsequent crop, too. However, such a crop in Bangladesh would take the place of a food crop, effectively halving the amount of food the land can provide.

Besides substituting for food crops, green manure crops would also require cutting and being plowed under the soil. Although plowing technology has advanced dramatically in many developed countries, the developing world uses mostly two-wheel tractors or rototillers. Thus plowing under high-biomass green manure or crop residues is a significant challenge.

Some researchers propose greater use of leguminous food crops to supply nitrogen for subsequent cereal crops. Where possible, some growers would love to expand pulses. However, even though the national pulse yields in South Asia appear stable, switching to more of these crops is quite risky for individual farmers due to diseases, unseasonable rainfall, and poor growing environments.

To make compost effectively, one has to have surplus plant biomass and cow dung. For the poor who have limited land and animals, this is quite difficult.

Surveys I have conducted in Bangladesh clearly show that growers who do have the ability to add organics to their land are richer and have more animals and larger land holdings. The poor must rely on purchased fertilizers, whether organic or chemical.

Growers in Bangladesh have told me that they would like to use more organics. But due to their cost and their limited availability, organic fertilizers are actually being used less and less each year. ❧

—Craig Meisner

1. Badgeley, C. et al. 2007. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems* 22:86-108.

What If Organic Farmers Joined Forces with Genetic Engineers?

Beginning in 1997, an important change swept over cotton farms in northern China. By adopting new farming techniques, growers found they could spray far less insecticide over their fields. Within four years they had reduced their annual use of the poisonous chemicals by about 70,000 metric tons—almost as much as is used in the entire state of California each year. Cotton yields in the region climbed, and production costs fell. Strikingly, the number of insecticide-related illnesses among farmers in the region dropped to one-fourth of their previous level.

This story, which has been repeated around the world, is precisely the kind of triumph over chemicals that organic-farming advocates wish for. But the hero in this story isn't organic farming. It is genetic engineering.

The most important change embraced by the Chinese farmers was to use a variety of cotton genetically engineered to protect itself against insects. The plants carry a protein called Bt, a favorite insecticide of organic farmers because it kills pests but is nontoxic to mammals, birds, fish, and humans. By 2001, Bt cotton accounted for nearly half the cotton produced in China.

> It is time to abandon the caricatures of genetic engineering that are popular among some consumers and activists and instead see it for what it is: a tool that can help the ecological farming revolution grow into a lasting movement with global impact.

For anyone worried about the future of global agriculture, the story is instructive. The world faces an enormous challenge: Its growing population demands more food and other crops, but standard commercial agriculture uses industrial quantities of pesticides and harms the environment in other ways. The organic farming movement has shown that it is possible to dramatically reduce the use of insecticides and that doing so benefits both farm workers and the environment. But organic farming also has serious limits—there are many pests and diseases that cannot be controlled using organic approaches, and organic crops are generally more expensive to produce and buy.

To meet the appetites of the world's population without drastically hurting the environment requires a visionary new approach: combining genetic engineering and organic farming.

This idea is anathema to many people, especially the advocates who have helped build organic farming into a major industry in richer countries. As reflected by statements on their websites, it is clear that most organic farming trade organizations are deeply, viscerally opposed to genetically engineered crops and seeds. Virtually all endorse the National Organic Standards Board's recommendation that genetic engineering be prohibited in organic production.

But ultimately this resistance hurts farmers, consumers, and the planet. Without the use of genetically engineered seed, the beneficial effects of organic farming—a thoughtful, ecologically minded approach to growing food—will likely remain small.

Despite tremendous growth in the past 15 years, organic farms still produce just a tiny fraction of our food; they account for less than three percent of all U.S. agriculture and even less worldwide. In contrast, during the same period, the use of genetically engineered crops has increased to the point where they represent 50 to 90 percent of the acreage where they are available. These include insect-resistant varieties of cotton and corn; herbicide-tolerant soybean, corn, and canola; and virus-resistant papaya.

After more than a decade of genetically engineered crops and more than 30 years of organic farming, we know that neither method alone is sufficient to solve the problems faced—and caused—by agriculture.

It is time to abandon the caricatures of genetic engineering that are popular among some consumers and activists and instead see it for what it is: a tool that can help the ecological farming revolution grow into a lasting movement with global impact.

By 2050, the number of people on Earth is expected to increase from the current 6.7 billion to 9.2 billion. To feed those people with current crop yields and farming practices, we will need to clear, fertilize, and spray vast amounts of wild land. Millions of birds and billions of beneficial insects will die from lost habitat and industrial pesticides, farm workers will be at increased risk for disease, and the public will lose billions of dollars as a consequence of environmental degradation. Clearly, there must be a better way to boost food production while minimizing its impact.

An alternative is to expand the number of organic farms which do not use synthetic pesticides and which thus support higher levels of biodiversity than conventional farms. Some organic farmers even retain patches of natural habitat on farms to provide shelter for wildlife. But at current crop yields, farming will still need to absorb huge amounts of additional land – land that is now home to wildlife and diverse ecosystems. A clear challenge for the next century is to develop more productive crops, not just better farming techniques, and genetic engineering has demonstrated great promise here.

One way to boost yields is to develop crops that can survive harsh conditions such as drought, cold, heat, salt, and flooding. Many of the world's poorest people farm in areas that are far from ideal, and freshwater sources are decreasing in quantity and quality throughout the world. Organic farming can help somewhat: Organically cultivated soil tends to hold water longer because of the higher levels of organic matter. Still, this approach has limits. Far more helpful would be new crop varieties designed to survive in difficult environments, and in the future this is where genetic engineering will likely have the most significant human and ecological impact. Crops with enhanced tolerance to drought, for instance, would allow farmers to produce more food using less water. Already there are varieties of genetically engineered wheat that can tolerate drought, as well as rice that can tolerate flooding and tomato plants that can tolerate salt.

Another important challenge is to fight pests and disease, which take an estimated 20-to-40-percent bite out of agricultural productivity worldwide. Reducing this loss would be equivalent to creating more land and more water. But current pesticide use is a health and environmental hazard, and organic and genetic engineering offer complementary solutions. Genetic engineering can be used to develop

Without additional yield increases, maintaining current per capita food consumption will necessitate a near **doubling of** the world's **cropland area** by 2050.

Data Source: Green, R. et al. 2005. Farming and the fate of wild nature. *Science* 307:550-555.

photo ©Igor Dutina/iStock.com

seeds with enhanced resistance to pests and pathogens; organic farming can manage the overall spectrum of pests more effectively.

Genetically engineered crops have already enjoyed major success against pests. For example, in field trials carried out in central and southern India, where small-scale farmers typically suffer large losses because of pests, average yields of genetically engineered crops exceeded those of conventional crops by 80 percent. In Hawaii, the 1998 introduction of an engineered papaya plant that could resist the papaya ringspot virus virtually saved the industry. There was no organic approach available then to protect the papaya from this devastating disease, nor is there now.

When engineering hits its limits, though, organic farming can help. For example, the Bt cotton that transformed Chinese farming kills caterpillars of only some species, so it cannot be a stand-alone solution for general insect control. In fact, after seven years of pesticide reductions in Bt cotton fields in China, populations of other insects increased so much that farmers had to resume spraying certain insecticides. Organic farmers, by contrast, control these secondary pests by introducing beneficial insects that feed on the pests and by rotating crops to reduce the overall pest populations.

Genetic engineering also helps achieve other goals of the organic farming movement. By reducing the use of pesticides and by reducing pests and disease, it can make farming more affordable and thus keep family farmers in business and assure local food security. It can also make food more nutritious: In 2011, plant breeders expect to release "golden rice," a genetically engineered variety that will help fight vitamin A deficiency in the developing world, a disease that contributes to the deaths of 8 million young children each year.

To successfully blend the two important strands of modern agriculture—genetic engineering and organic farming—we will need to overcome long animosity between the advocates of organic farming and conventional farmers. We also need to address the repulsion many consumers feel toward the idea of genetic engineering.

To many supporters of organic agriculture, genetically altering crops feels fundamentally wrong or unnatural. They believe that farmers already have enough tools for a productive and healthy farming system.

On an environmental level, many worry that genetically engineered crops will cross-pollinate nearby species to create a new kind of weed that could invade pristine ecosystems and destroy native plant populations. On a personal level, many consumers worry that genetically engineered foods are unsafe or unhealthy.

So far, however, it appears those concerns are driven more by technological anxiety than by science. Virtually all scientific panels that have studied this matter have concluded that pollen drift from genetically engineered varieties currently grown in the U.S. does not pose a risk of invasiveness. (However, this does not mean that future crop varieties will also be harmless: Each new crop variety must be considered on a case-by-case basis.) And in terms of food safety, a report by the National Academy of Sciences concluded that the process of adding genes to our food by genetic engineering is no riskier than mixing genes by conventional plant breeding.

Today 70 percent of all processed foods in the U.S. have at least one ingredient from genetically engineered corn, cotton, canola, or soybean. Unlike the well documented adverse effects of some pesticides, there has not been a single case of illness associated with these crops.

Pitting genetic engineering and organic farming against each other only prevents the transformative changes needed on our farms. There seems to be a communication gap between organic and conventional farmers and between consumers and scientists. The stakes are high in closing that gap. Without good science and good farming, we cannot even begin to dream about establishing an ecologically balanced, biologically based system of farming and ensuring food security. ❧

—Pamela Ronald

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