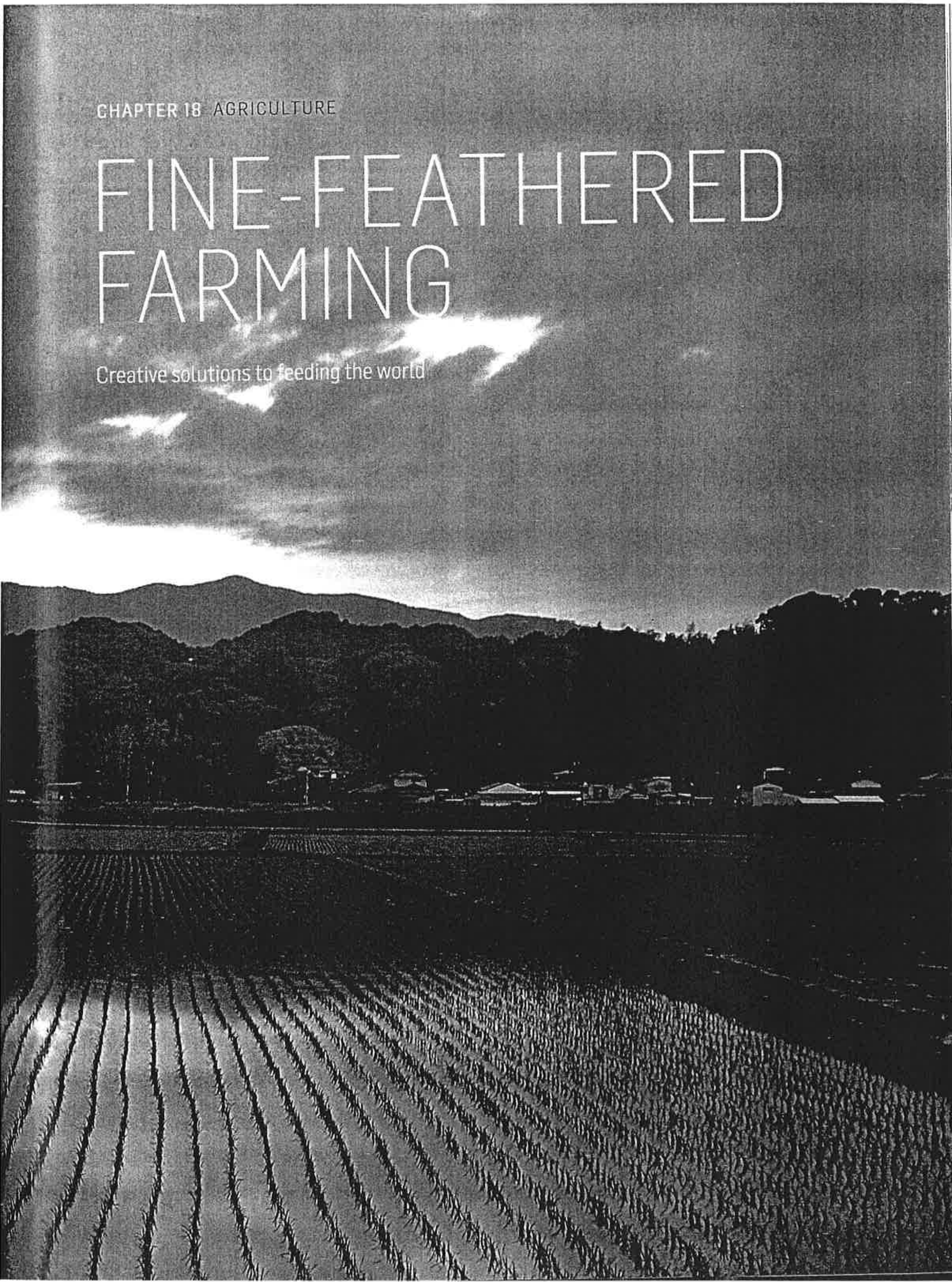
FINE-FEATHERED FARMING

Creative solutions to feeding the world



CORE MESSAGE

Modern industrial agriculture technologies and the use of genetically modified crops may help us feed the 9 billion or more people of the near future, but there are trade-offs to their use. To support the world's population, we can implement sustainable agriculture techniques as well as look to nature for farming practices that increase productivity with less environmental impact.

GUIDING QUESTIONS

After reading this chapter, you should be able to answer the following questions:

→ What modern industrial agriculture methods are used to produce food, and what are the advantages and disadvantages of these approaches?

→ Why does raising livestock often come with a higher environmental impact than plant crops?

→ How can we sustainably produce crops or raise animals for food?

→ What are the advantages and disadvantages of organic farming?

→ What is the focus of the Green Revolution 2.0, and what are the advantages and disadvantages of this technology?

In Japan, the quiet rice paddies of Takao Furuno.

If there's one thing Greg and Raquel Massa hate, it's weeds—all varieties, but especially the azolla—an insidious fernlike plant that grows on the surface of water. Each spring, azolla plants invade the couple's rice farm, snaking their way through the dense, muddy paddies that stretch for miles along the Sacramento River near Chico, California, strangling young rice plants and forcing Greg into an endless and tedious battle.

The rivalry—Massa versus azolla—has spanned three generations. Greg's grandfather, Manuel Massa, planted the family's (and some of California's) first rice crops on the same land that Greg and Raquel now manage, in 1916. Back then, rice farming was a hard and uncertain life; Manuel was largely powerless against the azolla, which in some seasons claimed his entire crop.

By 1962, when Greg's father, Manuel Jr. took over, American ingenuity and modern science had completely changed the nature of the fight. Heavy doses of chemical herbicides enabled him to obliterate the weed. And specially bred higher-yield rice varieties, along with modern farming equipment and a heavy dose of chemical fertilizers, made the family farm both efficient and profitable.

Of course, that modern approach had its own problems. For one thing, it relied on cheap energy and lots and lots of water, both of which are in much shorter supply these days. For another, it impaired ecosystem services, often gravely, because it involved clearing huge swaths of land to increase production, and focusing all resources on a single crop. On top of that, chemical fertilizers and pesticides were expensive and not especially good for the land.

Greg and Raquel wanted to find a better way. So when they took over in 1997, they converted a portion of their farm to **organic agriculture**. Instead of synthetic fertilizers and pesticides, organic agriculture employs more natural or "organic" techniques in the growing of crops. This type of farming uses fewer chemicals and in some cases may produce more nutritious food. For example, research by Washington State University soil scientist John Reganold showed that organically grown strawberries had a longer shelf life and higher level of antioxidants than conventionally grown berries. But organic farming forced Greg and Raquel to battle weeds much as the first Manuel had: with great difficulty.

The trick was to lower water levels enough to kill the weeds, but not so much that the rice crop also died. Each day, Greg would wade into the paddies to see how the rice plants were faring against the azolla. Some weeks, he worried his entire crop would die. After a few seasons, the Massas started to despair: How could they make their farm environmentally friendly without losing their livelihood to an army of mangy weeds?

The Massas' story is the story of American farming, and by extension, of global agriculture; it's the story of how we feed ourselves. And on a planet where population is exploding, it's also a story of constant change.

The biggest of these changes, the ones that helped Greg's father thrive, came in a midcentury wave of scientific development and technological innovation collectively known as the **Green Revolution**. The Green Revolution—which took place between the 1940s and the 1960s—was a coordinated, global effort to eliminate hunger by improving crop performance and bringing modern agricultural technology to developing countries. Working across the globe, scientists, farmers, and world leaders introduced developing countries to technologies—such as chemical pesticides, sophisticated irrigation systems, synthetic nitrogen fertilizer, and modern farming equipment—that

◉WHERE IS CHICO, CALIFORNIA?

organic agriculture Farming that does not use synthetic fertilizer, pesticides, or other chemical additives.

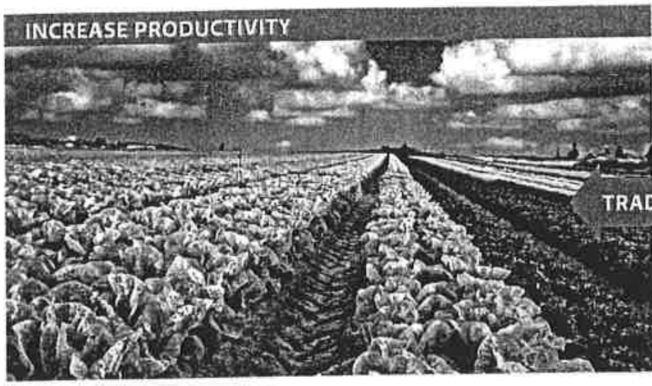
Green Revolution Plant-breeding program in the mid-1900s that dramatically increased crop yields and led the way for mechanized, large-scale agriculture.

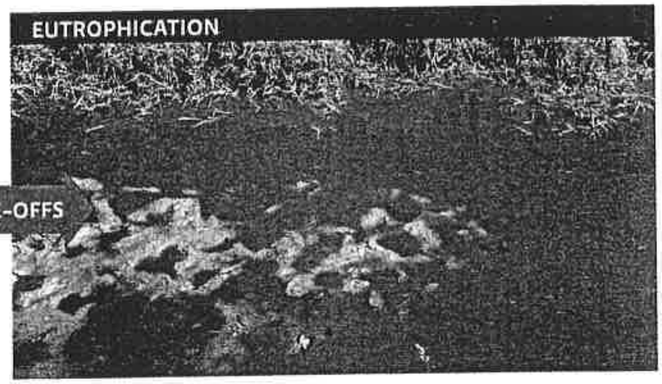
eutrophication Nutrient enrichment of an aquatic ecosystem that stimulates excess plant growth and disrupts normal energy uptake and matter cycles.

Infographic **18.1** | **THE USE OF FERTILIZER COMES WITH TRADE-OFFS**

BENEFITS

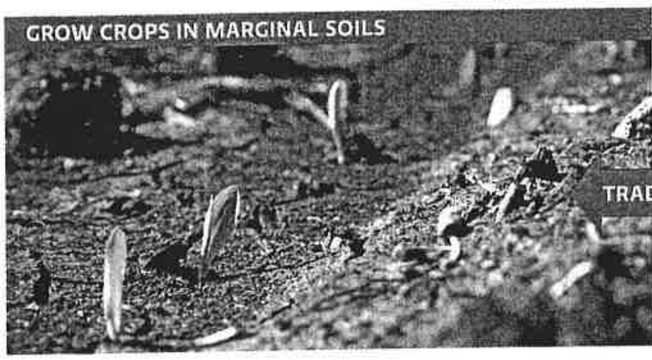
PROBLEMS

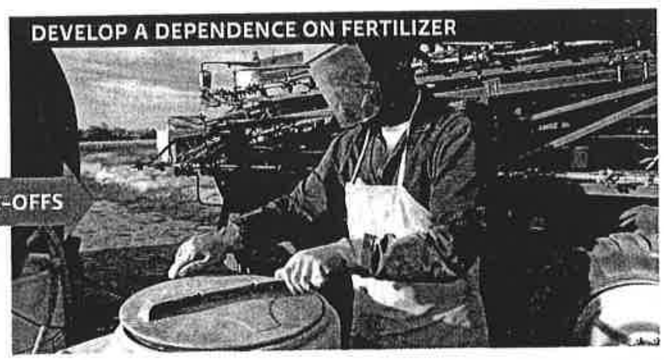




↑ Fertilizer can greatly increase productivity of the soil and is required for many of the high-yield varieties now under industrial cultivation.

↑ Runoff pollution that contains fertilizer can cause algal blooms that block sunlight and prevent underwater photosynthesis, resulting in oxygen deprivation and the death of many aquatic organisms.





↑ Fertilizers help crops grow in areas that may not otherwise be able to support agriculture. This may be the only way to farm in many areas of the world and would help increase local food supplies.

↑ Addition of a fertilizer can cause the soil to become more depleted of nutrients. The addition of a limiting nutrient boosts growth but this extra growth pulls other nutrients out of the soil, requiring even more fertilizer in the future.

most industrialized nations had already been using for decades. They also introduced some novel technology, namely new high-yield varieties of staple crops like maize, wheat, and rice. High-yield varieties (HYVs) are those plants that have been selectively bred to produce more than the natural varieties of the same species, usually because they grow faster or larger or are more resistant to crop diseases.

The combination of these forces (HYVs plus existing technology) resulted in a 1,000% increase in global food production and a 20% reduction in famine between 1960 and 1990. Thanks to this pivotal chapter in our history, most experts agree that we are now producing enough food to feed every one of the planet's 7 billion or so mouths.

As impressive as these gains are, they have come at a huge environmental cost. It turns out that while heavy doses of fertilizer can indeed boost crop production, the excess fertilizer (whatever is not used by the plants) is easily washed from fields by rain and modern irrigation practices. When this excess, or run-off, enters waterways, it causes algae and other aquatic plants to grow into massive blooms. These blooms, which are at the water's surface, block sunlight, shutting down underwater photosynthesis and ultimately causing hypoxia, oxygen-poor regions that threaten aquatic life. This process, known as **eutrophication**, has been a significant problem in the United States, where nutrient run-off from farms in Iowa and other "Corn Belt" states has created a virtual dead zone in the Gulf of Mexico (see Chapter 16). [INFOGRAPHIC 18.1]

Pesticide application has also proved problematic. To be sure, pesticides kill pests and thus dramatically reduce the amount of crops lost each year to infestation. But because they are toxic, pesticides also pose a threat to human and ecosystem health. And as scientists quickly discovered, pest populations can develop resistance to almost any pesticide that we invent. When this happens, farmers must either use more of the original pesticide (which is even more toxic and spurs additional pesticide resistance), or find a different pesticide altogether. As resistance to that next pesticide develops, the cycle repeats itself. It's like an arms race between humans and pests, with the deck perpetually stacked in favor of the pests (see Chapter 10). [INFOGRAPHIC 18.2]

Environmental damage is not the Green Revolution's only shortcoming. Even though we are producing enough food to feed the planet, many people still go hungry each day. In 2010, the United Nations estimated that some 925 million people were underfed (not getting enough calories) or malnourished (getting enough calories but not enough essential nutrients). Such poor nutrition is a root cause of more than half of the world's diseases and more than half of all child deaths (roughly five million children per year).

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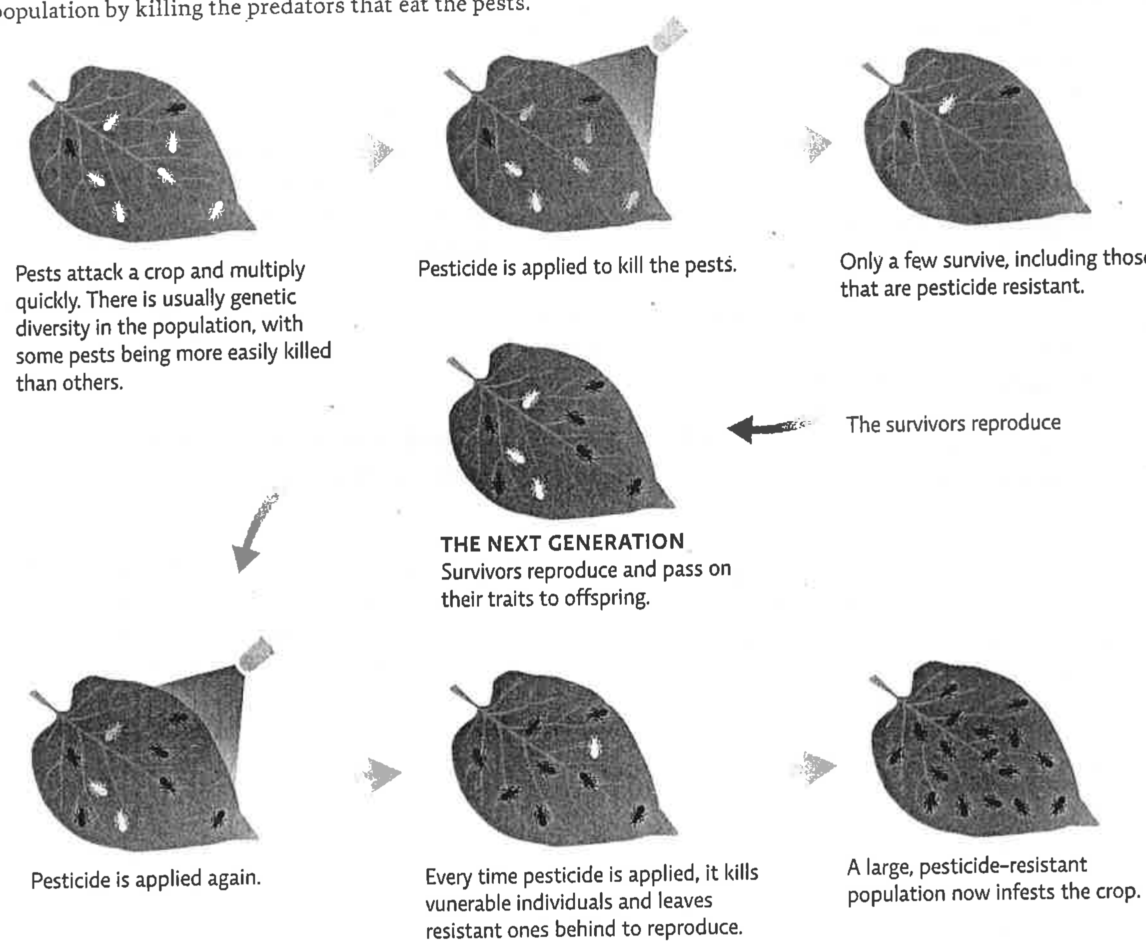
Why? Because even though we are producing enough food, our production is unevenly distributed around the globe. Some countries, like the United States, produce much more food than they need. In other countries, like

Infographic 18.2 | **EMERGENCE OF PESTICIDE-RESISTANT PESTS**

↓ Exposure to a pesticide will not make an individual plant resistant; it will likely kill it. However, if a few plants survive because they happen to be naturally resistant, they will breed and their offspring (most of which are also pest resistant) will make up the next generation. Over time, the original pesticide will no longer be effective and will have to be applied at a higher dose or a different pesticide will have to be used. Application of a pesticide might even increase the size of the pest population by killing the predators that eat the pests.



↑ Greg Massa, right, with rice plants in hand.

Haiti, degraded land, natural disasters, and a lack of other resources make food self-sufficiency impossible. Armed conflict is another factor, in Africa especially. It often destroys existing crops and prevents new ones from being planted.

Meanwhile, food has become a global commodity, instead of a locally produced good, meaning that it can be shipped huge distances for the right price. Most food now travels some 1,500 miles from producer to consumer, using up an unsustainable amount of fossil fuel. The more **food miles** a product travels before reaching the consumer, the greater the ecological footprint of that food.

Into this constellation of problems, an additional 3 billion people will soon be born. Global population is expected to reach 10 billion by 2050; experts say that to feed that many mouths we will need to produce twice as much food as we are now producing. That will mean either farming more land or devising new production-boosting technologies. But we are already farming most of the cleared, arable land out there; to farm more, we would have to clear more forests, and thus destroy more natural habitats, species, and ecosystem services. And while genetic engineering offers hope that we can produce more food on the same amount of land, most experts agree that no such technology will enable as dramatic an increase as is needed.

As land degrades, population soars, and global climate warms, the story of how we feed ourselves is changing once again. We are already growing crops on most of the cleared, arable land out there and using all that modern technology has to offer. This time, technology may not be enough. Instead of turning to the lab, we may have to turn back toward the natural world. In searching for a new weapon against the azolla, Raquel found a Japanese rice farmer who was doing just that.

The natural world holds answers to some environmental problems.

Takao Furuno was, by most standards, a very successful industrial rice farmer, with annual yields among the highest in southern Japan. But it was a tough grind. Each year he was forced to put all his earnings back into the next year's crop—pesticides, herbicides, irrigation, and fertilizer —so that despite his success, he and his family were left with very little for themselves at the end of each season.

In searching for a better way, he turned, as he often did, to his forebears to see what he could learn from their knowledge. He was surprised to discover that they used to keep

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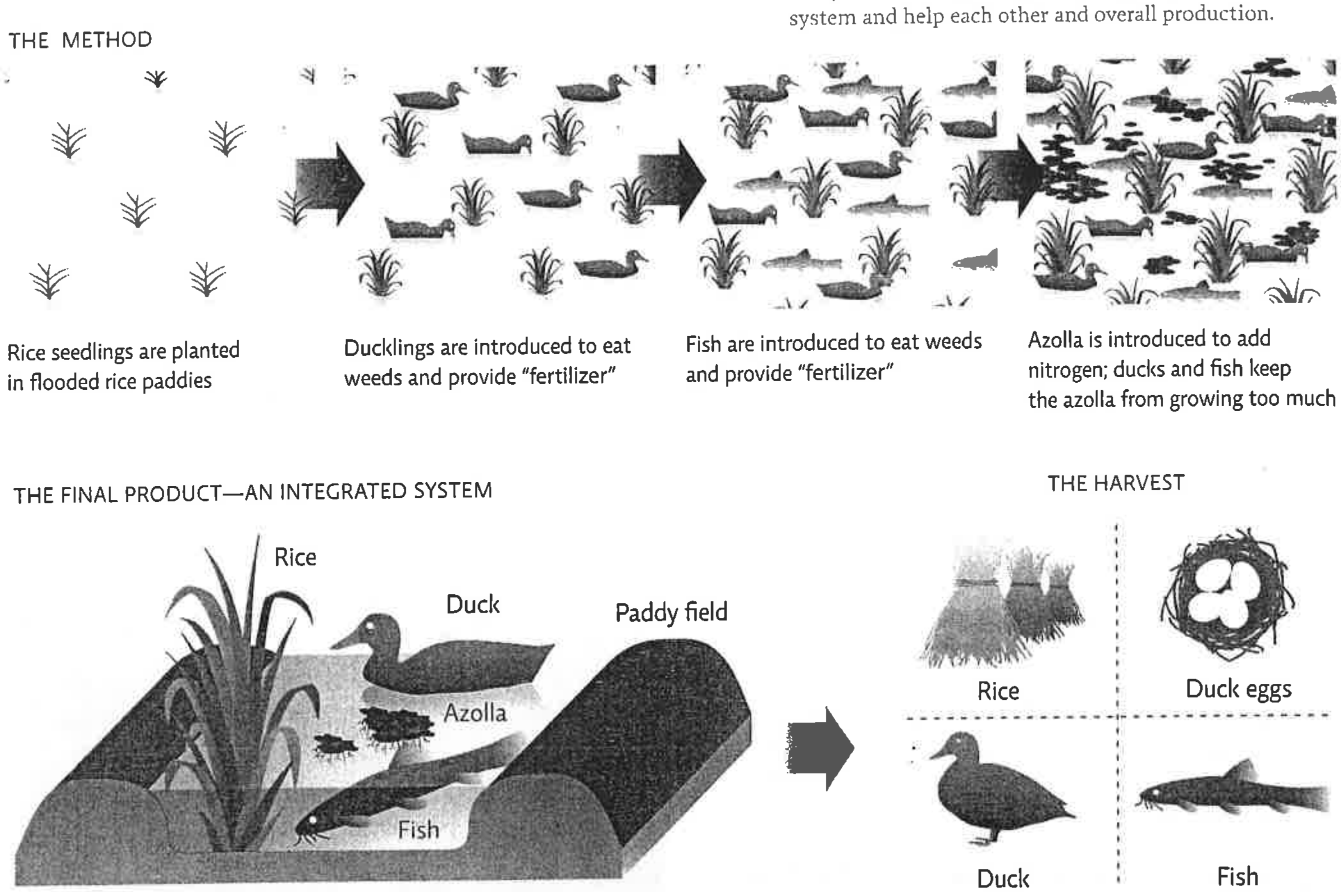
food miles The distance a food travels from its site of production to the consumer.

Infographic 18.3 | **INTEGRATED FARMING: THE DUCK/RICE FARM**

↓ Takao Furuno's farm is a self-regulating, multiple-species system that naturally meets the needs of the farm ecosystem. The species present all play a role in the system and help each other and overall production.



ducks in their rice paddies. Most rice farmers consider ducks a pest, albeit a slightly cuter one than the azolla. Adult ducks eat rice seeds before they have a chance to grow, and as they forage, trample young seedlings into the mud. This creates open patches of water, which in turn, invite only more ducks. "If you're not careful, you end up with a big problem pretty quickly," says Raquel.

But ducklings, Furuno soon realized, were too small to do such damage; for one thing, their bills were not big or strong enough to extract seeds from mud. Instead, they ate bugs and weeds. Azolla was one of their favorites.

Furuno's forebears also grew loaches—a type of fish—in their paddies. The loaches would eat azolla and could be harvested and sold as food.

Together, the ducklings and loaches would keep the weed from strangling the rice crop; but they would not completely eliminate the azolla the way a heavy dose of pesticides would. Furuno quickly discovered that, when kept at this benign concentration, the azolla (which contain symbiotic bacteria that produce nitrogen) actually fertilize the rice. In fact, between the nitrogen from the azolla, and the duck and fish droppings, he soon found that he no longer needed to spend money on synthetic fertilizer.

There were other financial gains, too. Duck eggs, duck meat, and fish all fetched a good price in the market. And because he was no longer using pesticides, he could also grow fruit on the edges of his rice field. (He opted for fig trees, a crop he could harvest yearly without having to replant).

When raising ducks, fish, and rice crops together, Furuno discovered the root crowns (where the root meets the stem) of rice plants increased to about twice the size that they had been in his old industrial system. A larger root crown meant more rice. "We're not exactly sure why the crowns grew," Furuno told an audience of American farmers at a recent convention in Iowa. "But the ducks seem to actually change the way the rice grows. It's got something to do with the synergy of the whole system." [INFOGRAPHIC 18.3]

In the decade and a half since Furuno began duck/rice farming, his rice yields have increased by 20-50%, making his among the most productive farms in the world, nearly twice those of conventional farmers. Independent researchers have verified his results, including the Bangladesh Rice Research Institute which recommends the technique to Bangladeshi farmers. And by now, some 10,000 Japanese farmers have followed his lead; the Furuno method is also catching on in China, the Philippines...and California.

Some industrial agricultural practices have significant drawbacks.

By presenting an alternative way to grow both rice crops and duck meat, Furuno's methods confront two of the Green Revolution's biggest legacies: monoculture crop production, and concentrated animal feeding operations (CAFOs) for livestock.

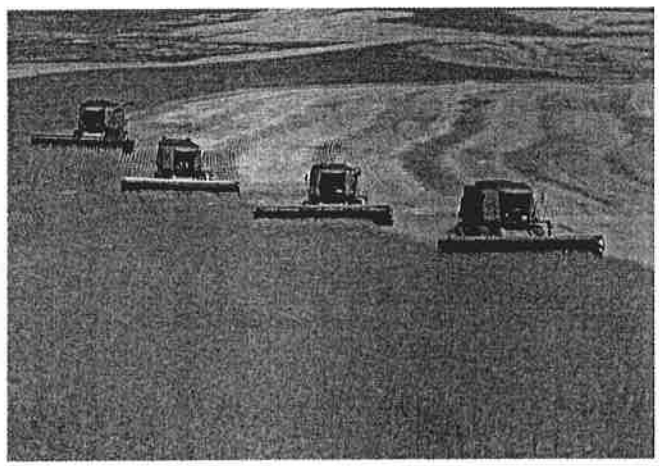
In **monoculture** farming, a single variety (genetically identical individuals) of a single crop (rice or corn or soybeans, for example) is planted over huge swaths of land. The uniform crops of a monoculture are easier to plant, maintain, and mechanically harvest. This makes mass production easier, which in turn makes for a more bountiful harvest.

In a **Concentrated Animal Feeding Operation (CAFO),** livestock are raised in confined spaces, with a focus on raising as many animals in a given area as possible. They are fed a nutrient rich diet of grain and soybean (in the case of cattle, this diet is supplemented with some hay) and are generally not permitted to graze or roam free. CAFOs are highly productive; they minimize the amount of land that is used; and because animals are so concentrated and confined, it is easy to harvest the animals' manure and sell it as fertilizer. Since about the mid-1900s, high-density feedlot operations like this have been the most common method of raising cattle in the United States. Today, poultry (chickens and ducks) and pigs are also predominantly raised in CAFOs.

But for all their benefits in efficiency and production volume, monocultures and CAFOs present a number of disadvantages.

monoculture Farming method in which one variety of one crop is planted, typically in rows over huge swaths of land, with large inputs of fertilizer, pesticides, and water.
Concentrated Animal Feeding Operation (CAFO) Many meat or dairy animals are reared in confined spaces, maximizing the number of animals that can be grown in a small area.

↑ Cattle herding into a pen in Lubbock, Texas.



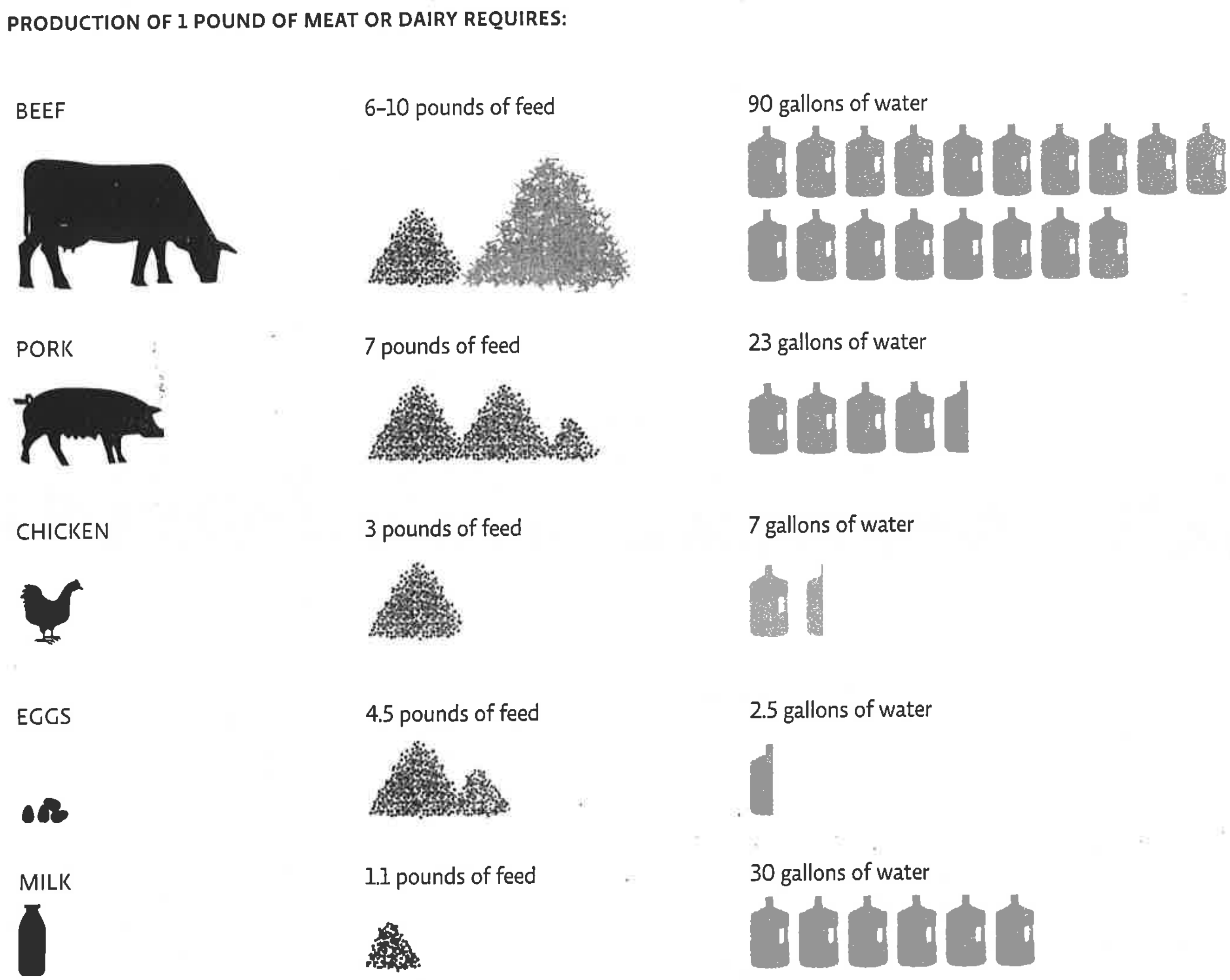
↑ Harvesting wheat with four John Deere combines in Montana.

For starters, both monocrop agriculture and CAFOs contribute heavily to global warming. Clearing so much land to grow food reduces the amount of carbon that can be sequestered by natural vegetation through photosynthesis. Also, fertilizer and livestock emit greenhouse gases. In fact, according to the UN Food and Agriculture Organization, livestock is responsible for some 18% of anthropogenic greenhouse gases.

In monocrop agriculture, the crop that is chosen is not necessarily locally adapted. Instead of focusing on which crop is best suited to the existing ecosystem, farmers focus on those crops with the highest market demand, and thus the highest dollar value. This shift, combined with the exponentially higher volume of plants, has made most farms heavily dependent on external inputs—water, pesticides, and fertilizer—that are added to the farm from outside its own ecosystem. "In the 1920s, half of Iowa's farms produced 10 commodities each," says

Infographic **18.4** | **GROWING LIVESTOCK: FEED AND WATER NEEDS**

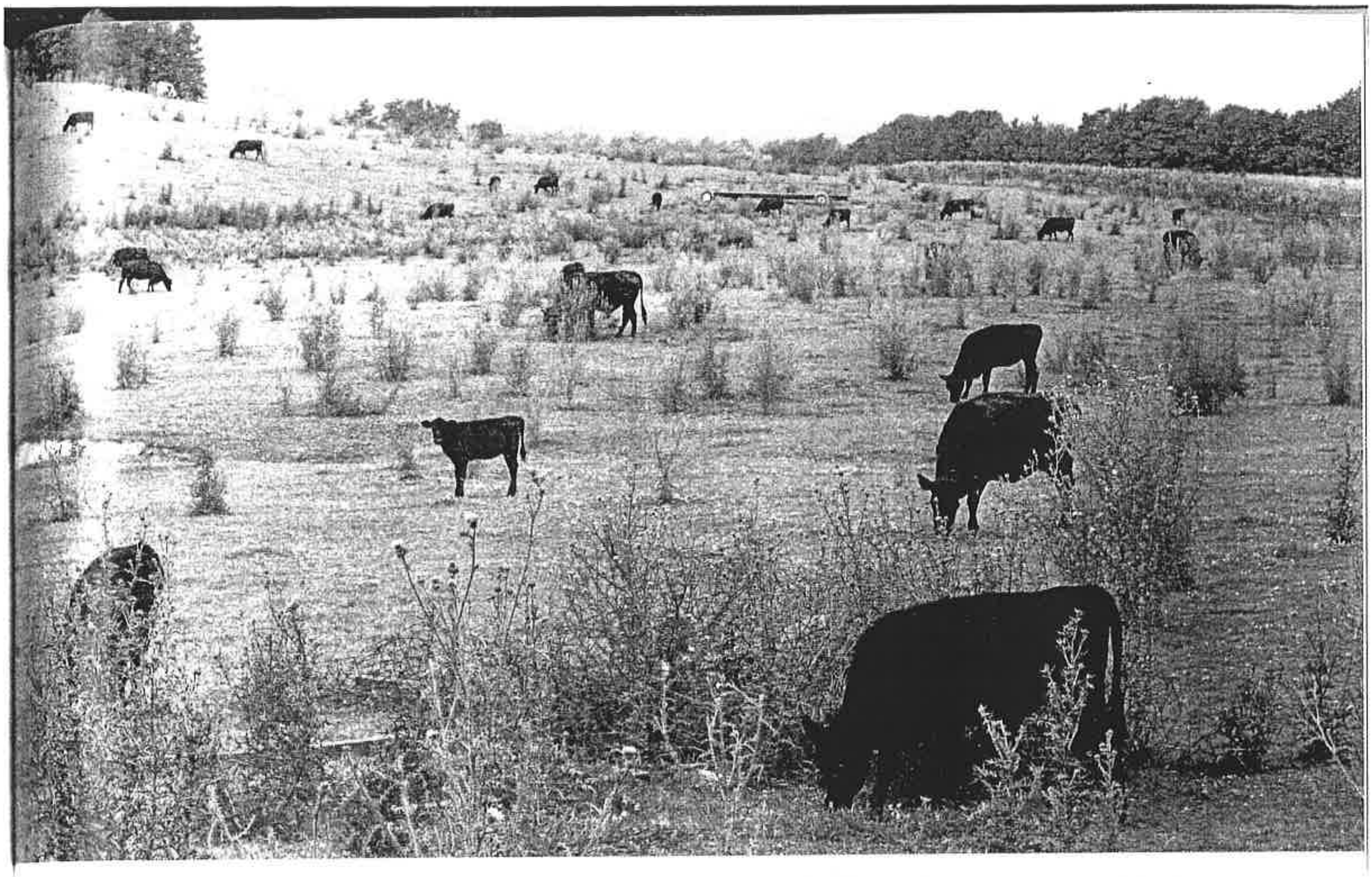
↓ Feed conversion rates show how much usable product is produced from the food an animal is fed. We never see 100% conversion because the animal has already used most of the energy it has consumed in its life in day-to-day activities; however, some species are better at converting feed to usable product than others are. It may also be surprising how much water is needed to produce meat and dairy product; much of it goes to grow the feed.



Fred Kirshenmann, a distinguished fellow at Iowa State University's Leopold Center for Sustainable Agriculture. "Today, 80% of the state's cultivated land is exclusively corn or soybean. Farming systems that were once supported by complexity and diversity of species have now been replaced by reliance on inputs."

This dependence makes monocrop agriculture both expensive and environmentally taxing. Heavy farm machinery compacts soil and increases its erosion. Use of irrigation can result in soil salinization; as water evaporates from the soil, salts are left behind and become so concentrated that crops can no longer grow.

CAFOs come with their own set of problems: They are environmentally taxing and ethically questionable. While the high grain diets fed to confined animals certainly maximize growth, they are not necessarily good for the animals' health. Such diets may cause liver and stomach disorders, increased susceptibility to infections, and even death. In addition, crowded living conditions (viewed by some as inhumane) make CAFO animals more vulnerable to disease, forcing farmers to use heavy doses of antibiotics to prevent sickness. Such heavy use contributes to antibiotic resistance, which threatens the health of the animals and humans. Resistant microbes that develop in the livestock can make their way into the water supply



↑ Cows at Polyface Farm in Virgina are grass fed and graze using the rotation method. This method is closer to a traditional ecological system than conventional farming.

and spread to other food sources. They can also be passed directly to consumers in the meat itself.

CAFOs have drawn the ire of environmentalists who point out that the grain and soybean used to feed all those livestock would feed far more humans than the meat we harvest from the animals actually does. The reason for this has to do with **feed conversion rates**—how quickly and efficiently any given animal converts the food it eats into body mass (that we then eat). Cattle have a high food conversion rate, meaning it takes a lot of feed to produce a gallon of milk and even more to produce a pound of meat. It also takes a lot of resources (namely, water and fossil fuel) to produce that feed. Chickens and pigs have slightly better feed conversion rates and thus require slightly fewer resources to grow, but not by much. [INFOGRAPHIC 18.4]

In the United States, a niche market has developed for "grass-fed" beef, which is produced from animals that are raised on pasturelands as opposed to CAFOs. Grass-fed animals don't gain weight nearly as rapidly as feedlot animals do; they eat less and spend more time moving around, so they don't get quite as fat. But the meat and milk they produce is healthier—it has less saturated fat and more omega-3 fatty acids than CAFO-generated beef. And the animals themselves live better lives—rather than being confined in a tight space, they are free to roam the grasslands and eat the food (namely grass) that they have evolved to process and digest. In fact, unlike CAFO livestock, grass-fed animals represent a net gain for the human food supply; they eat grasses that we can't eat (from land that is unsuitable for human crops), and turn it into beef and dairy products that we can eat (see Chapter 12).

The ducks on Furuno's farm are like the grass-fed cattle: They are raised in a humane environment, without any undue environmental costs. But whether or not his methods would work as well on the other side of the planet was an open question.

Sustainable agriculture techniques can keep farm productivity high.

Greg and Raquel were well versed in the problems of modern agriculture. Before settling in California to take over the family farm, they had worked as tropical ecologists

feed conversion rates How much edible food is produced per unit of feed input.

↑ Ducklings in the Massa Organics rice fields.

possible," says Greg, "so that we would not need artificial inputs to run the system." They also took their sustainable ideals to the next level and built a straw house to live in—made of two feet thick walls of rice bale, coated on both sides with plastic or stucco—that can withstand the unforgiving heat of a Chico summer and maintains a steady temperature almost entirely by itself. The house is fire proof, rodent proof, and as Greg likes to joke, bullet proof, too.

Furuno's method of duck/rice farming would be a good fit for the Massas. Not only would the rice plants rely on natural fertilizers and natural pest control, but the duck eggs and meat produced would be more humanely grown than those produced by factory farms. The ducks would grow up in ponds, not crammed together on slats in a barn with no access to swimming water. They would get to splash around, and express their "duckiness," as Raquel put it.

When the ducks first arrived on the Massa farm, they were just 24-hours old, cotton ball–sized tufts of yellow feathers. The Massa children cared for them in wooden crates in their barn. But as Raquel soon learned, small ducklings grow mighty fast. In just 2 weeks, they were large enough to turn loose. Furuno had advised stocking about 100 ducks per acre, but Greg and Raquel did not want to sacrifice that much land for this first attempt, so they fenced off just a quarter-acre instead. This amount of space provided plenty of room for their 120 ducks to swim and forage in, but as it turned out, not enough food to support them. "They quickly ate all the weeds in the field," says Greg. They also trampled some of the rice plants in their pond because their section of field was too small. But, even as they ran out of weeds to eat, the baby ducks stayed away from the rice plants. Just as Furuno had insisted they would.

Genetically modified crops may help feed the world.

Though promising, methods like the ones Furuno and the Massas are implementing represent only part of the solution to our emerging food problems. Critics say that by itself, organic farming will never produce as much food as industrial agriculture has, and neither organic nor current industrial practices will be enough to feed 10 billion people. So as population swells, scientists are working on another solution, one that has given rise to its own debates and controversies: genetic engineering.

Genetic engineering forms the basis for what some farmers and scientists like to think of as the **Green Revolution 2.0**; it involves manipulating genes to increase productivity or to make it possible to grow crops in places they normally wouldn't—like marginal land, in drought-plagued regions, or on fields doused in pesticide and herbicide. **Genetically modified organisms (GMOs)** are organisms that have had their genetic information modified in a way that does not occur naturally. This usually involves transferring new genes for desirable characteristics—such as pest resistance, drought resistance, or increased nutrient production—from one species to another, creating a **transgenic organism**. [INFOGRAPHIC 18.7]

Most existing GMO crops are altered to have greater pest resistance (for example, Bt transgenic plants), but scientists are also working on drought-tolerant varieties of plants and have had some success in creating nutritionally enhanced food. The most notable example is golden rice, which was genetically modified to produce extra beta carotene. Deficiencies of beta carotene, which produces vitamin A, is a leading cause of blindness in children.

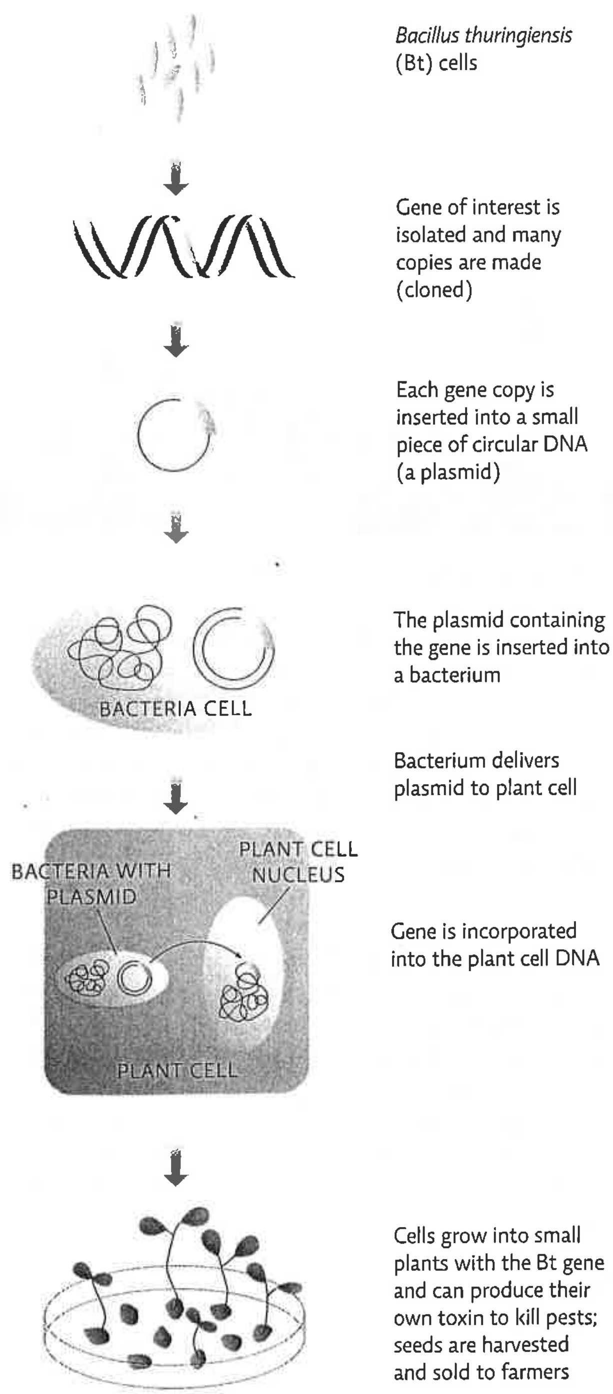
In the United States, more than 75% of processed food contains GMOs, including 85–90% of our corn, soybean, and cotton. Most of these crops have an herbicide-tolerant (Ht) gene added so that they can withstand huge doses of herbicides. Scientists are also working to add genetically modified animals to our food supply. AquaBounty has developed a genetically modified Atlantic salmon that grows much faster than normal (thanks to genes from the larger Chinook salmon) and is currently seeking approval from the FDA to bring the fish to market. If approved, this would be the first GMO animal food product sold in the United States. [INFOGRAPHIC 18.8]

In other parts of the world, however, including China and the European Union, GMOs have been met with fierce opposition from consumers who worry about the long-term health impacts and environmental consequences.

One concern is that the genes introduced into domestic crops could escape into the natural world and be incorporated into other plants for which they were not intended. If a pest-resistance gene were transferred to a weed species, for example, it could allow the weed to grow more aggressively and outcompete other plants, including our crops. This has already happened in the United States.

Infographic **18.7** | **GENETIC ENGINEERING CAN PRODUCE ORGANISMS WITH USEFUL TRAITS**

↓ Genetic material can be transferred from one organism to another. Plants that receive a gene from the bacterium *Bacillus thuringiensis* (Bt) to produce a toxin that kills pests will produce the toxin themselves, giving the plant protection from many pests.



Green Revolution 2.0 Focuses on the production of genetically modified organisms (GMOs) to increase crop productivity or create new varieties of crops.

genetically modified organisms (GMOs) Organisms that have had their genetic information modified to give them desirable characteristics such as pest or drought resistance.

transgenic organism An organism that contains genes from another species.

Infographic **18.8** | **EXAMPLES OF GMOs**

TYPE OF GMO	EXAMPLES
HT (herbicide-tolerant) crops are not killed by the herbicide so the herbicide can be sprayed on the crop/soil directly, where it will kill weeds but not the crop.	Bromoxynil-tolerant canola & cotton Glyphosate- (Roundup-) tolerant corn, cotton, soybeans Imidazolinone-tolerant wheat
Bt crops contain a gene from *Baccillus thuringiensis*, a naturally occurring bacterium that produces a toxin that kills some pests.	BT corn, potatoes
Nutritionally enhanced food: Genes inserted can increase the amount of a particular nutrient or allow the crop to produce a nutrient it would not normally produce.	Golden rice
GM animals are being developed for the food supply.	Salmon that grow faster Pigs that produce more omega-3 fatty acids

↑ Giant Ragweed (*Ambrosia trifida*).

So far, 16 weed species have acquired a gene for herbicide tolerance (Ht). These so-called super weeds, including giant ragweed and pigweed, can be found in 22 states and can tolerate all the herbicide a farmer can spray. They take over entire fields, stop combines, and are tough to clear by hand.

Another problem, say opponents, is that GMOs are patented and owned by a few multinational corporations, which makes them more expensive than traditional seeds, and thus a bad option for developing countries. Much of the hunger seen in the world today arises not from lack of food but from an inability of the disempowered to access it. Putting even more of our food supply under the control of a few multinationals could only make this worse.

In the Sacramento Valley, where the Massa farm is located and where virtually all of the U.S. rice crop is grown, farmers are split over the merits of genetic engineering. Some see the advantage of having crops that can better tolerate drought, floods, and disease. "The climate is changing," says one of Greg's neighbors. "We see drier seasons and more extreme weather than we ever have before. And eventually we will need some breed of rice that can endure those changes." But others, including Greg Massa, say that growing genetically engineered rice anywhere, in any quantity, poses a threat to their farms and livelihoods.

Here's why: In 2006, small amounts of experimental strains of genetically engineered rice crept into the U.S. food supply. Nobody knows how the strain, engineered by the company Bayer to be herbicide resistant, escaped from the Arkansas storage bins where it was being kept. However, when news spread, European retailers pulled all U.S. rice from their shelves, sending rice prices plummeting and threatening the sanctity of the Massa farm and all of its neighbors. "The problem is, even the threat of contamination can kill our businesses," says Greg. "So it's really a danger to grow it anywhere, at least until it wins wider approval. And in the meantime, there are other ways to combat weeds. The duck farming proves that."

At any rate, GMOs are already here, and aren't likely to disappear anytime soon. The bottom line: This technology will almost certainly help address some of our food issues, but as with all new technology, we will have to weigh risks and benefits very carefully with each step forward. And as the global population swells, we will probably need all solutions—crops that have been engineered to resist weeds, and crops grown in more integrated, natural systems, like the duck/rice farms of Japan and California—to feed the world.

For the Massas, duck/rice farming has proven to be the best possible solution to the challenges of modern agriculture. They ended up with duck meat to sell, and though they didn't take any precise measurements of yields during their first trial run, their rice crops did not appear to suffer at all. "We learned a couple of things," Raquel says. "The ducks trampled some of the rice in their pond, which would not have been a problem if we had used a larger section of the field. I also think we used the wrong breed of duck. They were a little too large to move effectively between the dense plants, and they were not active enough in their foraging abilities. These ducks were bred to sit around all day and eat and gain weight quickly for industrial meat production. We are currently researching which breeds to try next."

Still, in the end, the Massas harvested both rice and duck meat. The key to successful duck/rice farming is to harvest the ducks before they get big enough to trample rice plants or strong enough to pluck rice seeds from deep within the mud. The hard part isn't knowing when to do this, but having the resolve for what comes next: killing and eating the ducks. The Massa family struggled, but ultimately felt good about the outcome. "I know the conditions in which they were raised were more humane than 99% of the meat ducks in this country," says Raquel. "They had it good and you can taste that in the finished product."◉

Research articles referenced in this chapter:
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BRING IT HOME

➲ PERSONAL CHOICES THAT HELP

Making food choices for your health and wellness, as well as for the vitality of the environment, requires some thought. Becoming an educated consumer is one way you can reduce your environmental impact, eat a nutrient-rich diet, and contribute to the public dialogue about the safety and sustainability of our food systems.

Individual Steps

→ Support local independent farms by shopping at farmers markets; buying a share in a community-supported agriculture (CSA) group in your area; and frequenting restaurants that serve food grown locally. For more information see www.localharvest.org.

→ Reduce the amount of animal products you eat and try to buy free-range and grass-fed meat whenever possible.

→ Grow your own food. Transportation of food contributes heavily to emissions and fossil fuel usage; planting just a few edibles can greatly decrease your food footprint.

→ Buy organic, especially for frequently eaten produce that typically is heavily treated with chemicals such as apples, celery, lettuce, strawberries, and peaches; this reduces the chemical residue you ingest and the chemicals released into the environment, and helps provide safer working conditions for people in the agriculture industry.

Group Action

→ Find like-minded people to start a community garden in your area. Community gardens allow apartment dwellers to grow their own food in empty lots or in public spaces. For information on community gardens, see www.communitygarden.org.

Policy Change

→ GMOs offer promise for feeding the world's population, but like all technologies, pose some risks, both known and unknown. Write letters to your newspaper asking for coverage of this issue. Support policies that require the testing, labeling, and traceability of GMO products.