Chapter 15

Optimizing Food Production

THE MAIN IDEA

Agriculture employs much chemistry.

15.7 Quality Agricultural Practices

Agriculture is the organized use of resources for the production of food. Whether these resources—mainly topsoil and fresh water—will be available for future generations depends on how well we manage them now. We already know from experience that pesticides and fertilizers cannot be applied liberally without threatening both topsoil quality and our supplies of clean groundwater (not to mention our health and that of the planet).

Over the past several decades, there have been strong movements toward developing methods and technologies that will sustain agricultural resources over the long term. Problems associated with irrigation, for example, can be solved by **microirrigation**, which is any method of delivering water directly to plant roots. Microirrigation not only prevents topsoil erosion but also minimizes the loss of water through evaporation, which in turn minimizes the salinization of farmland. One method of microirrigation is shown in **Figure 15.28**.

Organic Farming Is Environmentally Friendly

For controlling pests and maintaining fertile soil, the conventional agricultural industry is now looking at the efforts of many small-scale farmers who have demonstrated that significant crop yields can be obtained without pesticides or synthetic fertilizers. This method of farming is known as **organic farming**, where the term *organic* is used to indicate a concern for the environment and a commitment to using only chemicals that occur in nature.

To protect against pests, organic farmers alternate the crops planted on a particular plot of land. Such *crop rotation* works fairly well because different crops are damaged by different pests. A pest that thrives on one season's crop of corn, for example, will do poorly

FOR YOUR INFORMATION

Those living in the agricultural regions of the arid southwestern United States are most familiar with the accumulation of visible salty sediments, as shown in the inset of Figure 15.27. Agricultural salinization, however, has been a problem since the beginning of agriculture. Archeological evidence shows that the fall of the Sumerian society of ancient Mesopotamia was likely due in part to the accumulation of salts on farmlands irrigated by waters of the Tigris and Euphrates rivers in what is now Iraq. Civilizations along the Nile river in Africa, however, survived through the millennia because, unlike the Tigris and Euphrates, the Nile river floods seasonally, which allows a seasonal flushing of accumulated salts.

Λ Figure 15.28

The microirrigation method known as drip irrigation delivers water through long, narrow strips of punctured plastic tubing. The system provides only as much water as the plants need.

on the next season's crop of alfalfa. Crop rotation also mitigates the depletion of minerals and nutrients. For fertilizer, organic farmers rely on compost, shown in **Figure 15.29**. They also include nitrogen-fixing plants in their crop rotation schedules.

Many claims are made that food produced organically is better for human consumption. Chemically, however, the molecules that plants absorb from synthetic fertilizers are the same as those they absorb from natural fertilizers. If organically grown produce tastes any better or is more nutritious than conventionally grown produce, the reason likely has to do with the genetic strain of the produce or with the greater attention paid to growing conditions, such as the health of the soil and the amount of water made available to plants.

Mostly, organic farming tends to be benevolent to the environment. In addition to avoiding the potential runoff of pesticides and fertilizers, organic farming is energy efficient, using only about 40 percent as much energy as conventional farming. A large portion of the energy savings arises because the manufacture of pesticides and fertilizers is energy intensive.

Because much organically grown food, such as that shown in **Figure 15.30**, is grown locally, by purchasing it, you help support local farmers. Ultimately, though, your purchase of organically grown food is a vote in favor of environmentally friendly methods of farming.

< Figure 15.29

Odor-free backyard compost bins are easy to build and maintain. The secret is to optimize the exposure to atmospheric oxygen, which favors aerobic decomposition.

Figure 15.30

Market forces often result in higher prices for organically grown food. A product can bear this USDA organic seal if at least 95 percent of its ingredients are certified organic.

CONCEPT CHECK

Which are made of organic chemicals, organically grown foods or conventionally grown foods?

CHECK YOUR ANSWER Regardless of whether they are grown with natural fertilizer or synthetic fertilizer, all foods are made of organic chemicals—carbohydrates, lipids, proteins, nucleic acids, and vitamins. A thoroughly rinsed conventionally grown carrot may be just as good for you—or even better—as one grown without the use of synthetic fertilizers and pesticides. The *organic* in organic farming is a term used to designate a natural method of farming friendly to the environment.

Integrated Crop Management

To meet concerns about sustaining agricultural resources over the long term, groups from industry, government, and academia have identified a whole-farm strategy called **integrated crop management** (ICM). This method of farming involves managing crops profitably with respect for the environment in ways that suit local soil, climatic, and economic conditions. Its aim is to safeguard a farm's natural assets over the long term through the use of practices that avoid waste, enhance energy efficiency, and minimize pollution. ICM is not a rigidly defined form of crop production, but rather a dynamic system that adapts and makes sensible use of the latest research, technology, advice, and experience.

One of the more significant aspects of ICM is its emphasis on multicropping, which means growing different crops on the same area of land either simultaneously, as shown in **Figure 15.31**, or in rotation from season to season. Like organic farming, multicropping achieves significant pest control, and it can be used to improve soil fertility. For example, nitrogen-generating crops such as legumes are a good complement to nitrogen-depleting crops such as corn.

An important component of ICM is **integrated pest management** (IPM), one of the aims of which is to reduce the initial severity of pest infestation. This can be accomplished through a number of routes. When a farm is started, for example, only crops that fit the local climate, soil, and topography should be grown. This selectivity makes for crops that are hardy and pest-resistant. Crops should also be rotated as much as possible to reduce pest and

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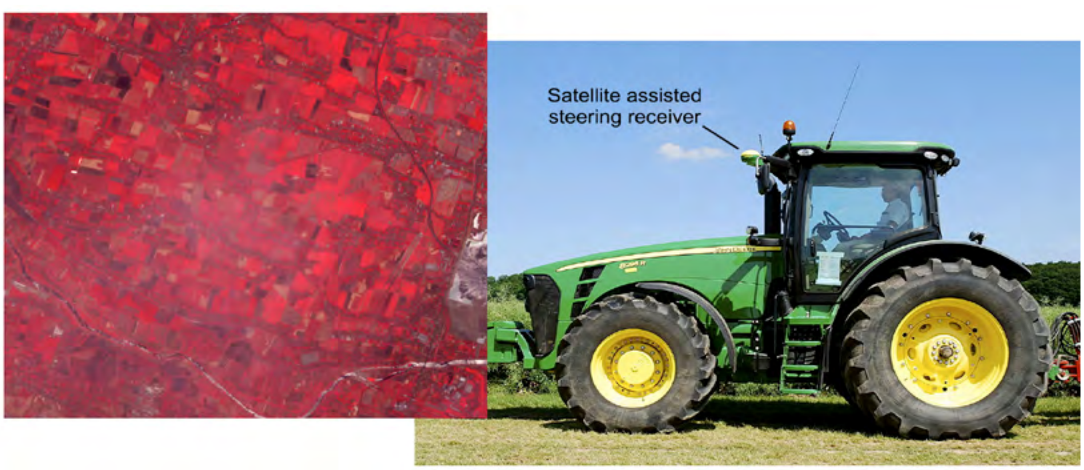
The outer coat of the naturally occurring rice grain contains bran as well as a number of valuable nutrients. Natural rice is transformed into white rice by milling away this outer coat. But why mill away this outer coat when it is so nutritious? The outer coat also includes fats that, over time, oxidize to make the grain turn rancid. Thus, unprocessed rice, also known as brown rice, is not well suited for long- term storage.

Figure 15.31 >

Complementary crops such as legumes and corn are grown in alternating strips to enhance soil fertility. The strips follow the contour of the land to minimize erosion from rainwater or irrigation.

weed problems. Another IPM strategy is growing tree crops or hedges either around the perimeter of a farm or interspersed throughout the farm. These trees and hedges provide habitat, cover, and refuge for beneficial insects and such pest predators as spiders, snakes, and birds. As an added benefit, the trees and hedges also protect the land from wind erosion. Yet another IPM strategy is to breed and cultivate plants that have a natural resistance to pests. For centuries, this was accomplished by selectively mating plants that showed the greatest resistance. Today, this age-old method is quickly being supplanted by the techniques of genetic engineering.

Another aim of IPM is to minimize the use of pesticides. For example, many farmers now use the global positioning satellite (GPS) system to target precise pesticide applications. Using infrared satellite photography, illustrated in **Figure 15.32**, and careful walk-through assessment of field conditions, farmers can match pesticide blends with crop needs. Computers link application equipment with the GPS satellites, which "beam" pesticide application adjustments every few seconds as a farmer moves across a field. This same technology also works well with selective delivery of synthetic fertilizers.



Λ Figure 15.32

(a) Infrared satellite images reveal much information about our agricultural lands. Shades of red, for example, indicate crop health, browns show how much pesticide has been applied, and black shows areas prone to flooding. (b) In a practice called precision farming, a computer system using data from high-resolution satellite imagery guides a GPS-equipped tractor to pinpoint nutrient and pesticide placement.

Many other methods of pest control can be used in place of chemical pesticides or in combination with them to minimize the need for these agents. Depending on the availability of labor, egg masses or larvae can be hand-picked off plants. Instead of using herbicides, weeds can be tilled under. An insect population can also be controlled through various biological approaches, such as by introducing large numbers of sterile insects into a population or by introducing natural predators, as shown in **Figure 15.33**.

Another way to control the proliferation of insects is to modify their behavior through the use of **pheromones**, which are volatile organic molecules that insects release to communicate with one another. Each insect species produces its own set of pheromones, some as warning signals and others as sexual attractants. Sexual pheromones synthesized in the laboratory can be used to lure harmful insects to localized insecticide deposits, reducing the need for spraying an entire field, as depicted in **Figure 15.34**.

READING CHECK

How are pheromones used to protect crops?

CONCEPT **CHECK**

Describe Integrated Crop Management.

CHECK YOUR ANSWER

A method of farming that involves managing crops profitably with respect for the environment in ways that suit local soil, climatic, and economic conditions.

Figure 15.33

The almond trees on the right side of the road were decimated by spider mites. Those on the left were protected by the introduction of spider mite predators.

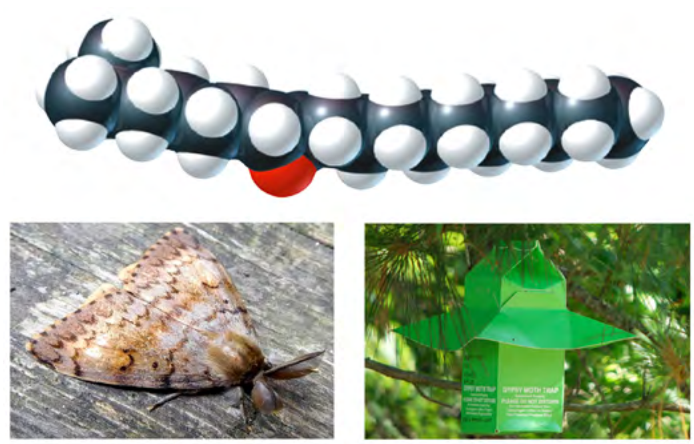


Figure 15.34

Female gypsy moths emit the pheromone disparlure (top) to entice male gypsy moths (bottom left) into mating. The males are so sensitive to this compound that they can detect one molecule in 10^{17} molecules of air. This astounding sensitivity enables them to respond to a female that may be more than 1 kilometer away. However, they can also be tricked into responding to insecticide traps laced with synthetic disparlure (bottom right).

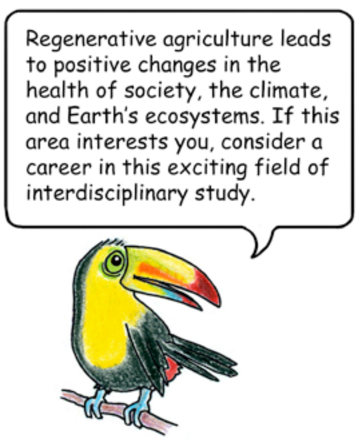
Figure 15.35

(a) Wheat is an annual crop that must be planted each year. (b) Wheat can be hybridized with a wild grass cousin, *Thinopyrum*, to create a food-bearing perennial crop that grows from one season to the next. As an added benefit, the hybrid grain is low in gluten.

Regenerative Agriculture

The farming techniques described above are part of a movement known as **regenerative agriculture**, which holds that proper agricultural practices can be sustainable as well as help us to recover from past harmful practices. This includes promoting biodiversity, particularly with the use of crop rotation. The plowing of agricultural land should also be minimized while also avoiding the use of synthetic pesticides and fertilizers.

An example of a crop particularly suited to these principles is Kernza® developed by the Land Institute in Salinas, Kansas. This crop is a perennial grain, which means it grows continuously and does not need to be replanted every year (**Figure 15.35**). This, in turn, means that the field need not be plowed routinely, which saves energy as well as protects the soil. Furthermore, the roots grow deep, which means the plants are effective at transporting carbon from the atmosphere into the soil. As described in the next chapter, this is an example of *carbon sequestration,* which is greatly needed to help combat growing levels of atmospheric carbon dioxide, a potent greenhouse gas.



Regenerative agriculture also promotes proper grazing management for livestock. The idea is that animals free to roam across large spans of land help to restore the soil fertility, which, in turn, is better able to sequester carbon. This is in contrast to holding livestock within crowded pens or buildings where animal wastes become concentrated and thus toxic, not only to the animals but to the local environment.

While pasture-fed beef is more environmentally sound than factory-fed beef, there remains a deeper problem. The production of beef and other animal products tends to be harmful to the environment no matter how the animals were raised. Livestock, such as cattle, account for about one-third of our total emissions of methane, which is a greenhouse gas up to 80 times more potent than carbon dioxide. Also, the amount of arable pasture land available for livestock is limited. Furthermore, livestock themselves require vast amounts of feed. For example, more than half of the grain grown in the United States is presently consumed by these livestock rather than directly by humans (**Figure 15.36**). As described in the trophic structure diagram

< Figure 15.36

Pasture-fed cattle are more sustainable than factory-fed cattle, but neither can be relied upon for feeding the world and helping to maintain a sustainable environment.

of Figure 15.1, the greatest energy efficiency is achieved by eating as low on the food chain as possible. As the world population quickly grows past 8 billion of us, a meat-based diet for all is impossible to achieve. Consider why fossils of the Tyranosaurus Rex dinosaurs are so rare? Answer: They were meat eaters at the top of the food chain, which necessarily means they were few in number. Both in terms of available calories and also support for sustainable agriculture, we are wise to focus on developing our plant-based diets.

Nature is sophisticated, and if we are to work with nature in a sustainable way, our methods must also be sophisticated. New and improved techniques provide the farmer with a menu of possible actions in response to nature's ever-changing parameters. With each action, however, the farmer must be aware of its potential environmental impact, both locally and globally. In this sense, the human who farms sustainably is not dominating nature but rather working with it. That's good chemistry.

CONCEPT **CHECK**

Are there any dissolved salts in a mountain stream?

CHECK YOUR ANSWER

Land contains a variety of salts. As water runs over and through the land, these salts dissolve in the water. In general, the farther the water travels, the saltier it becomes. Thus, even water that has traveled only a short distance, which is the case with a mountain stream, contains some salts. So, the answer to this question is a qualified "Yes, but not enough to make the water undrinkable."