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CHAPTER
4

# Precision Agriculture and Emerging Technologies

**Essential Question**

*How can technology be leveraged to enhance sustainable agriculture?*

## *Before You Read*

Look at the *Words to Know* list. Write definitions for the words you know. Put the words you cannot define into a separate list. As you encounter the words in your reading, compare your definitions to those in the chapter and complete the definitions for the words you did not know.

## *Chapter Outcomes*

*After studying this chapter, you should be able to:*

- Describe the equipment and systems used in precision agriculture.
- Describe the role of information technology in agriculture.
- Explain the contribution of biotechnology to agricultural practices.
- Describe sustainable methods of energy production.
- Identify alternative fuels.
- Explain the role of technology in agriculture.
- Explain ways to manage agricultural technology to reduce harmful impacts on the environment.

## *Words to Know*

anaerobic digester
as-applied map
automation
autonomous
base station
biofuel
biologging
biotechnology
diesel exhaust fluid (DEF)
differential correction
drone
engine control unit (ECU)
exhaust gas recirculation (EGR)
forced induction
gene mapping
genetic engineering
geographic information system (GIS)
global positioning system (GPS)
methane digester
photovoltaic system
precision agriculture
reference map
remote sensing
rover
selective catalytic reduction (SCR)
sensor
site-specific management
soil compaction
soil conductivity
soil nutrients
soil pH
sustainability
sustainable energy
technology
telematics
thematic map
unmanned aerial vehicle (UAV)
variable-rate technology (VRT)
yield
yield map
yield monitoring

***Technology*** is the application of science to solve a problem. Technological advances occur through interactions among multiple disciplines, such as engineering and physics. Production agriculture has benefited tremendously from the incorporation of technological advances achieved in other industries:

- The Industrial Age brought mechanization and synthesized fertilizers to agriculture, **Figure 4-1**.
- The technology age introduced genetic engineering and automation.
- The Information Age brings the potential for integrating these advances into a sustainable agriculture production system that makes the best use of valuable resources.

As agricultural production confronts new challenges, such as a growing global population and the loss of arable land, the industry will be furthered challenged to find new technologies that increase production without compromising the environment or public health. Our first step in that direction is precision agriculture.

## Precision Agriculture

***Precision agriculture*** is a systematic approach to site-specific agricultural management. Simply put, it is the use of technology to reduce emissions and increase crop yields and profitability while reducing the amount of traditional inputs, such as water, land, fertilizer, and pesticides, needed to grow crops. The technology used to accomplish these goals gathers data from the field and directs the machinery to apply precise amounts of seed, fertilizer, pesticides, herbicides, and water to specific geographic locations.

The primary tools used in precision agriculture include global positioning systems, geographic information systems, sensors and controllers, and remote sensing/digital imagery. These tools all use computers to manipulate data for interpretation. The adoption of these technologies continues to grow. The USDA NAAS reported that in 2021, 25% of farms in the United States used precision agriculture technologies within the last 12 months to manage crops or livestock.

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**Figure 4-1.** A John Deere combine harvesting soybeans is an example of mechanization of farm equipment. *How did farmers harvest crops before these types of machines were available?*

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**Figure 4-2.** This Tier 4 emissions-compliant tractor is equipped with a GPS receiver.

## Global Positioning System

For precision agriculture and site-specific management to work effectively, a farmer or rancher must have a geographic reference point to associate with any variability within or between fields. Global positioning systems are used to provide geographic reference data. The ***global positioning system (GPS)*** used in the United Sates is navigation system made up of a network of satellites placed in orbit around Earth. Other countries, such as Russia and China, have similar satellite systems. Collectively, these are called *global navigation satellite systems*. These satellites transmit a coded signal referencing their location as they orbit Earth. A GPS receiver compares the time a signal was transmitted by a satellite and the time it was received to determine the user's position and display it on an electronic map. See **Figure 4-2**.

### Satellites and Correction Factors

To accurately place seed and fertilizer in a field where it will be most effective for increasing yields, farm machinery must be precisely guided to a geographic reference point in the field. The GPS receiver on the equipment must have signals from at least three satellites orbiting Earth. The GPS receiver then calculates the time for the signal to travel from each satellite, which then can be used to calculate the distance between the receiver and each of the three satellites. This process, known as *trilateration*, determines the receiver's latitude and longitude position on Earth. A fourth satellite is needed to calculate the elevation of the reference point. Any differences in latitude and longitude of a known location are considered measurement error and must be corrected mathematically. Most handheld GPS units are accurate within 10 meters. Positional accuracy of the receiver can commonly be affected by:

- Satellite signal blockage by objects such as buildings, bridges, and trees
- Indoor or underground use
- Signals reflected off buildings or walls ("multipath")

### GPS Receivers and Differential Corrections

A mobile GPS receiver, such as a handheld device, is referred to as a ***rover***. These units can be fixed to a number of types of agricultural machinery from combines to tractors. The rover units rely on a stationary GPS receiver referred to as a base or base station. The GPS ***base station*** serves as a location with a known latitude/longitude. With a known location, a differential correction can be calculated. ***Differential corrections*** are techniques used to increase the accuracy of the GPS signal. The rover GPS unit can correct its own GPS calculated position using the error differential. Several corrections that can improve GPS accuracy are available to GPS users, including the following:

- The *Coast Guard Navigation Center System (CG NAVCEN)* is a network of transmitting towers that provide a free correction signal within approximately 10 meters. Users must purchase a beacon receiver to receive the free signal. However, these towers are not accessible (located within 300 miles of a navigable waterway) to many interior locations within the United States.
- The *Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS)* is another source for correction up to approximately seven meters. WAAS is available for anyone with a GPS unit that is WAAS-enabled.
- A *ground-based augmentation system (GBAS)* is a nonfederal source of correction that is often provided by local airports. GBAS is not commonly used for agricultural applications.

## Private Differential Correction Systems

There are private companies with differential correction systems that are available for a subscription fee. These use privately held satellites that are in *geosynchronous orbit* (a satellite that follows the orbit of Earth and maintains its position centered above one specific area of Earth as the Earth rotates). With these subscriptions, customers may pay for levels of accuracy from one meter to subcentimeter. These systems require a base station to correct error. With *real-time kinematic correction (RTK)*, corrections can be applied in real time using a radio frequency between the base station and the rover unit. With RTK, the units are in constant communications, relaying signals and calculating corrections as the unit travels in the field.

Satellite-based guidance for agricultural vehicles provides numerous benefits, including the reduction of skips and overlaps, increased ability to work in poor visibility, and lower operator fatigue. Additionally, the accuracy provided by these systems provides means to conduct spatial analysis and recordkeeping to facilitate decision making to ensure economic viability of an agricultural operation.

## GPS Guidance

Guidance is performed with GPS receivers in combination with either a navigation aid or an integrated steering device. Navigation aids, commonly referred to as *lightbars*, help operators visualize their travel position in relation to their previous travel. These aids indicate deviations from their desired travel so the operator can make steering adjustments. Auto-guidance options use either an integrated electrohydraulic control system or a mechanical steering device installed inside the tractor cab.

***Autonomous*** vehicles do not require a human operator to provide direction or control. Operation is controlled remotely or robotically, **Figure 4-3**. Autonomous vehicles rely on computers that collect and analyze data and then perform a function based on programmed algorithms. Most auto-guidance technology is semiautonomous, however. The operator starts and stops the machine, programs a desired travel path, and then takes control only when needed during turns and other maneuvers.

# Geographic Information System

***Geographic information system (GIS)*** software is a data management tool. It is used to map, model, query, and analyze large quantities of data within a single database according to a reference location. Google Earth®, Arc GIS®, and other software applications support this activity. Some programs download data onto removable storage media, such as a flash drive. Others upload the data to a cloud server.

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**Figure 4-3.** The robots are programmed to harvest a lettuce crop autonomously in an environmentally controlled building. *How is the robots' computer equipment protected from the humid air typically found in a greenhouse?*

## Pro Tip

### The Web Soil Survey (WSS)

The Web Soil Survey (WSS), operated by the USDA Natural Resources Conservation Service (NRCS), is a web application that producers can use to access soil and related information to aid in making decisions about land use. Users highlight areas on the map to collect relevant information.


USDA NRCS

## Types of Data

Data is often referenced with GPS coordinates. Examples of data include the following:

- ***Yield*** is defined as a measure of the product, such as grain. This is measured using the mass and moisture content of the grain.
- ***Soil conductivity*** is a measure of the soil's ability to hold and make water available to the plant. It is a good predictor of yield.
- ***Soil pH*** is the indication of a soil's acidity or alkalinity, which is measured by the concentration of hydrogen ions in the soil. Soil pH impacts the solubility of nutrients found in the soil and can limit the uptake of macronutrients provided through fertilizers.
- ***Soil nutrients*** (levels) are the substances or elements that plants need to grow and thrive. Major nutrients include phosphorus, potassium, and nitrogen.
- ***Soil compaction*** is a measure of the soil's density. It effects plant growth and development. High compaction rates result in poor root development and decrease water infiltration. See **Figure 4-4**
- Number of weeds or insects.

Data that is georeferenced can then be mapped to create management zones or grids. These zones or grids are used to make production decisions. Information is stored as a collection of layers that can be linked together by a common locational component, such as latitude and longitude.



**Figure 4-4.** Soil compaction occurs on a dirt road when vehicles regularly travel the same path. It is evident by the grass growing only in the center of road that the compacted soil deters plant growth.

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## Types of Maps

Mapping allows the farmer or rancher to visualize the data gathered from the field, such as yield, water usage, plant populations, and soil fertility, to make site-specific management decisions. See **Figure 4-5**. Many types of maps can be created using GIS software. Two major types are reference maps and thematic maps:

- ***Reference maps*** provide a model of what a geographic area looks like.
- ***Thematic maps*** provide information about a topic or theme, such as population density or soil type.

Maps are often created using layers. A *layer* is digital representation of a feature such as soil moisture or yield. These layers can be stacked on top of each other to create a diagram to show relationships within a field. These layers can also be created to show monthly rainfall, yield of a crop or soil nutrients, or a combination of these so that the producer can identify relationships that affect productivity.

*photo by Jeff Vanuga, USDA NRCS*

**Figure 4-5.** GIS applications can help farmers determine how best to use available land. Here, an NRCS soil scientist is using GPS technology to map soils in a farm field in Washington County, VA.

## Querying Spatial Data

The GIS software serves as a database for sorting, retrieval using queries of the data, or retrieval using queries of specific maps. (*Query* means to request data results or for action on the data from a database.) A producer must question the data for a specific value (data). Querying spatial data allows producers to determine where objects or events are in relation to each other. For example, this would be useful for a producer who is considering installing a buffer strip along a stream to prevent runoff. With GIS, if the stream has been mapped, a perimeter could be established around the stream to examine yield points of the field portion under consideration.

## Yield Maps

A valuable function of GIS software is the ability to use statistics as well as spatial analysis data. For example, the producer who is considering the buffer strip would be able to summarize and analyze for amount of yield, value of product, as well as operational costs to keep the field section in production. Yield data can then be linked to GPS coordinates to map out high and low productive sections of a field. These are referred to as ***yield maps***. Additional maps can be generated to visualize yields and profits generated from various sites. This information can be used in deciding to purchase or sell a field, as well as predict productivity for the future market. This type of strategy is known as site-specific management.

## Site-Specific Management

***Site-specific management*** involves observing and measuring the differences within fields, noting the specific locations of the differences, and using the information as a basis to make improvements in management or inputs. In site-specific management, different areas within fields are managed differently according to production needs as well as environmental concerns. The goal of this strategy is for decisions on resource application and production practices to match the varying needs of the crop or animal requirements. To determine variation in crop or animal needs, sensors are used to collect data. A ***sensor*** is a device that detects or responds to physical stimulus and transmits an impulse to provide data or operate a control. Controllers are used to apply resources based on these variations.

## Sensors and Controllers

Sensors are used to detect or measure physical properties and then transmit a signal to a measuring or control device. Examples of uses for sensors include recording rainfall, moisture, humidity, soil conductivity, mass, pressure, light, or temperature.


*photo by USDA NRCS staff member*

**Figure 4-6.** An example of a yield monitor used during harvest of a crop. Note the moisture and field area measured by the system.

***Yield monitoring*** uses load cells to measure weight and moisture sensors to measure moisture content during harvest, **Figure 4-6**. A computer calculates the weight of the crop by adjusting for moisture content. These sensors are typically controlled by a switch. On a combine, a switch is used to detect the position of the header. When the header is raised while turning at the end of the row, the switch signals the computer to stop collecting data from the yield-monitoring sensors.

## Variable-Rate Technology

Sensors and controls are used with a variety of machinery, including sprayers, irrigation pivots, as well as planter units. These systems use ***variable-rate technology (VRT)***. VRT enables farmers to vary the rate of crop inputs based on data collected from the field. Field zones are created using the GIS software that provides a map for the equipment controller during application. These maps are created on a computer and uploaded to the equipment controller. The equipment control will vary the real-time disbursement of the input, such as fertilizer, as it travels the field using the GPS.

Users can also create a digital ***as-applied map***. These maps are created using the equipment controller as the machinery operates in the field. The operator sets an application rate and the controller records the application data on a geo-referenced map file. These as-applied maps serve as a historical record of the application to review and reference when yield data is recorded.

## Remote Sensing/Digital Imagery

Some sensors capture reflected light wavelengths and use them to create digital images. Unlike other sensors, these sensors do not contact the object. Instead, they record the percentage of electromagnetic waves reflecting off an object, such as a plant. Sensors may use a multispectral or hyperspectral camera for this purpose. These sensors detect varying degrees of reflectance for one specific wavelength or for a series of wavelengths, and capture these reflectance values as a digital image.

A digital image is comprised of color dots or squares called *pixels* (picture elements). Images with higher resolutions have more pixels and create detailed images. High-resolution images can capture even the slightest variation in the colors of an object. Producers can use these images to detect pests or to check the overall health of the plants. Unhealthy or stressed plants will not absorb light waves as well as healthy plants. An example is the *Normalized Difference Vegetative Index (NDVI)*, which uses the ratio between infrared wavelength and the red wavelength absorbed by the plant. This index, ranging from –1.0 to 1.0, quantifies vegetative biomass and plant vigor for each pixel captured in the image. Unmanned aerial vehicles (UAVs) are commonly used to capture images.

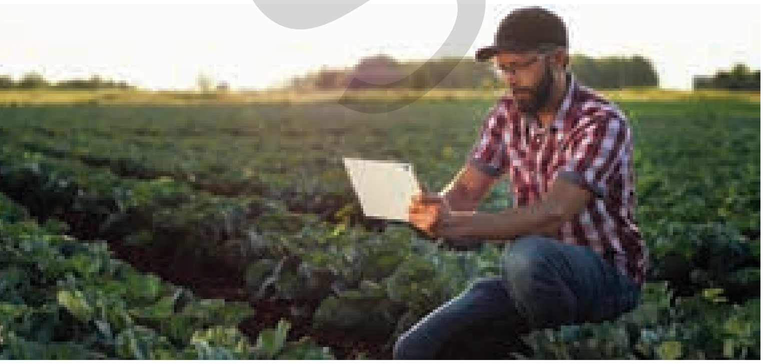

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**Figure 4-7.** A farmer can use mobile technology, such as a smartphone or tablet to record field data.

## Computer and Smartphone Applications

Increased computer and internet applications continue to change the way people communicate and share information. A smartphone or other mobile device provides the ability to map, calculate, measure, and instantaneously access a variety of information on location. See **Figure 4-7**.

In agriculture, information technology aids in calculating costs and analyzing data to make sound farm production decisions. Software applications, typically called *apps*, are continually being created, adapted, and modified for agricultural use. There are land-mapping apps that show topography, soils, bodies of water, and location. Other apps assist in the following tasks:

- Calculating tank mixtures for pesticides
- Determining weather
- Estimating crop yields
- Maintaining equipment
- Managing livestock
- Managing pest control
- Pricing commodities
- Viewing product labels
- Viewing safety data sheets

## Telematics

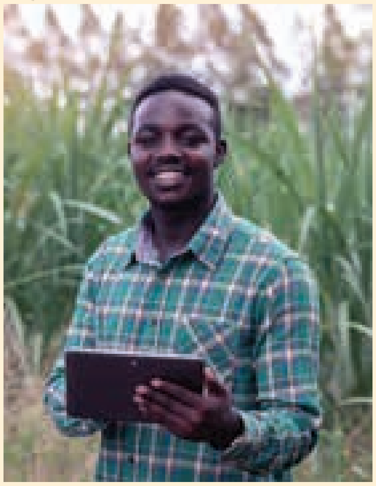
Farmers remotely collect and manage information from their field equipment with telematics technology. ***Telematics*** integrates wireless telecommunications with information technology to enable long-distance transmission of information in real time. In agriculture, electronic communication networks are embedded in farm machinery with GPS. These networks monitor and report information such as machine location, troubleshooting fault codes, hours of operation, and precision farming information, such as yield during harvest. Data is captured and transferred to the internet in real time via cellular or satellite systems to be analyzed.



### *STEM Connection*

#### Communication Tools

There are many types of information technologies, including radars, mobile phones, computers, and satellites. These technologies are used to create information systems for data retrieval and to help us solve problems or make decisions. The mobile apps used on tablets and mobile phones facilitate information retrieval and improve productivity.



arrowsmith2/Shutterstock.com

Wireless networks connect various computers and communication tools. The integration of sensors with wireless capabilities allows real-time data collection in the field. The information gathered and collected has traditionally been stored on physical servers—computer processers that allow people to share and store data. Today, many people and businesses use cloud servers to store data. A *cloud server* is a network of remote servers hosted on the internet to store, manage, and process data. Cloud servers are rented as virtual server space, eliminating the need for the user to rent or purchase physical servers. Cloud servers also provide a means of hosting software resources.

Daniel Jedzura/Shutterstock.com

**Figure 4-8.** UAVs equipped with high-definition cameras can be used to monitor plant and livestock health.

## Unmanned Aerial Vehicles

An ***unmanned aerial vehicle (UAV)***, commonly known as a ***drone***, is an aircraft that is remotely controlled by a human at a ground station. Drones may also be programmed to fly autonomously using a preprogrammed flight plan. UAVs are used for both civil and military operations. Civil applications include surveillance, police work, and firefighting. More recently, agricultural drones have been developed to aid in crop and livestock management. See **Figure 4-8**. These programmable aircraft can be equipped with thermal imaging devices or high-definition cameras to monitor plant or animal health. The cost of UAVs is falling as technology improves, but cost may still limit use on smaller production sites.

### Livestock and Crop Surveillance

Producers can use UAVs and telemetry to identify the herd's location, make head counts, and observe livestock behavior. They can also gather information that can be used to monitor and map the details of livestock movement, foraging, and other activities.

UAVs linked to GPS satellites can help monitor crops to identify problems that limit potential crop yield. The traditional practice of scouting crops for pests and other problems involved a labor force on foot that took samples from various locations. Today, a farmer can use a drone to take images of an entire crop and use color-contrast imaging to examine its overall health. The captured images can be linked with GIS software to map field borders and identify locations within a field that may need intensive management for pest or disease control. Prototypes have even been developed to allow for spot spraying of troubled areas within fields.

### UAV Regulation

The FAA established rules governing the use of UAVs. These rules are set based on the type of drone use. Individuals must register their drone with the FAA prior to taking flight. The type of user may be a recreational/modeler who is community-based, a certified remote pilot or commercial operator, a public safety or government user, or educational user.

**Ag Ed** *Connection*

### Research Proficiency Awards

New technology can be exciting. If this chapter piques your interest, consider conducting a Research SAE to qualify for an FFA Agricultural Proficiency Award. The Agriscience Research Proficiency Awards has a category for Power, Structural, and Technical Systems research. This category allows you to conduct research in a variety of areas that are mentioned in this chapter and throughout the text, such as precision technology, alternative energy sources, woodworking, metalworking, and welding.

Have a conversation with your agriculture teacher today about getting started with a qualifying Research SAE. Investigate information sources available locally or online and begin gathering information about a topic of interest. Your SAE could lead to an exciting career in agriscience and technology!

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## Wireless Sensor Networks

Innovations in livestock management technologies include ***remote sensing***, or ***biologging***, to record animal health variables. Wireless sensor networks convey and process data measurements pertaining to behavior and physiology. Limitations of this technology include battery life and costly maintenance. Reliable transmission of data over long ranges is also a concern. Animals wear collars that collect and transmit data to a central hub for analysis by the farmer, **Figure 4-9**. Biologging provides physiological data about the animal as the animal interacts with the environment. This information can aid livestock producers in identifying areas within a pasture or rangeland that have experienced high grazing. The data can then be used in mapping rotations for livestock within an area to reduce environmental impacts. Future areas of implementation include using the wireless sensors to serve as a virtual fence to cue animals to move to other areas to prevent overgrazing.

Ekaterina Bagautdinova/Shutterstock.com

**Figure 4-9.** Dairy cow equipped with a radio-collar used to collect data.

# Biotechnology

***Biotechnology*** is the use of living organisms to make or modify products that serve a useful purpose to humans. Recent advances in plant and soil systems have been focused on improving crop yield and health. New and valuable traits are being incorporated into crops, and new crop varieties are being developed. An early example is golden rice, **Figure 4-10**, which is biofortified with beta-carotene. Additional technologies have been developed to improve plant health monitoring as well as the management of limited resources while protecting the environment.

ArtisticPhoto/Shutterstock.com; zcw/Shutterstock.com

**Figure 4-10.** Golden rice, a variety of rice enriched with beta-carotene, is produced through genetic engineering.

## Genetic Engineering

***Genetic engineering*** is the scientific process of making changes to the genetic code of plants or animals to produce a desired trait, such as resistance to parasites. Scientists perform genetic recombination either by introducing foreign DNA to encode a desired trait in the plant (recombination) or by manipulating the genetic signals or material within the plant.

## Gene Mapping

***Gene mapping*** (determining the location of genes on chromosomes) gives agricultural scientists an increased understanding of the structure and function of crop plants and livestock. This knowledge allows the development of breeding practices to enhance crop and livestock species, resulting in breeds and varieties that are more nutritious, produce greater yields, and can better resist the negative effects of pests or other adverse conditions.

Like any research, gene mapping is a tool that can be abused. As research and development continues, legal and ethical issues continue to surface. Questions arise as to how the technology will be used. Other concerns focus on the research techniques used on animals and potential long-term adverse effects on humans.

## Genetically Modified Crops

Genetically modified crops (GMOs) are agricultural plants in which the DNA has been altered to introduce a trait that does not occur naturally in the species. These traits may include resistance to pests, disease, drought, spoilage, or chemicals. An example of crops modified for chemical resistance is Roundup Ready® crops. These crops are resistant to the active ingredient in Roundup®-brand herbicides, allowing the chemical herbicide to be sprayed over the crop to kill undesirable plants without harming the crop. Roundup Ready crops include alfalfa, canola, corn, cotton, sorghum, and soy. Other Roundup Ready crops, such as wheat, are being developed.

The main food source for approximately half of the world's population is rice. Modifying rice to increase production, increase nutrient content, or resist pests has the potential to combat hunger, poverty, and malnutrition on a global level. While genetically modified rice has been developed, controversy surrounds its use. A recent development is a non-GMO "green" super-rice that can resist adverse conditions and achieve above-average yields without fertilizer or pesticides.

### *Bacillus thuringiensis*

Some crops are modified to increase their resistance to pests. An example is the modification of certain plants to include *Bacillus thuringiensis (Bt)*, a soil-dwelling bacterium that is commonly used as a biological pesticide. Research has been performed on nonfood crops (tobacco and cotton) and food crops (potatoes and corn) with success. The use of Bt toxins in plants destined for human consumption requires extensive evaluation of their safety. Potential impacts on the environment must be evaluated as well. The advantage of Bt-modified plants is a decreased need for pesticides.

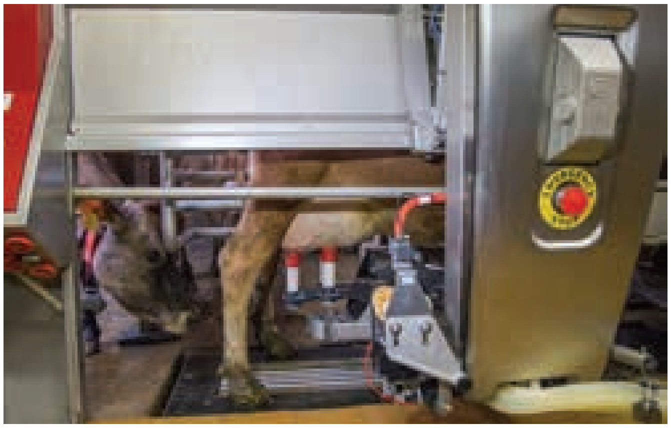
# Robotics

Robotic technologies that have been used successfully in other industries are now being used in agricultural applications. Robots reduce labor needs and strain on human health by eliminating repetitive movements that cause physical problems. They are currently used to select and pick ripe strawberries and tomatoes, and researchers are testing robots to pick lettuce, apples, and weeds. The robots, which may be autonomous or semi-autonomous, use computer vision and programming to perform these tasks. See **Figure 4-11**.

Robots are also used with livestock, as some cattle producers use robot feeders that automatically measure feed and distribute it to the cattle. Some dairy farmers are using robotic milking systems due to fluctuating costs and availability of laborers, **Figure 4-12**.

*ZappPhoto2/Shutterstock.com*

**Figure 4-11.** This automated robot uses computer vision and sensors to harvest strawberries grown in a greenhouse.



*Vladimir Mulder/Shutterstock.com*

**Figure 4-12.** A robotic milking system can help increase production while reducing labor costs.

The initial investment and learning curve may be high, but recent trends have shown that robotic milkers reduce employee costs and improve milk output, creating a feasible return on investment. Additionally, researchers have documented a decrease in mastitis (inflammation of udder tissue) and improved milk production because of more frequent milking sessions as cows adapt to the system.

### Artificial Intelligence

Artificial intelligence (AI) is a field of computer science that focuses on building smart machines capable of performing tasks that otherwise require human intelligence. This field looks at ways to program machines to analyze and interpret data for decisions such as watering or chemical applications.

Oleksii_Sidorov/Shutterstock.com

**Figure 4-13.** In areas that receive a dependable amount of sunshine or wind, electricity can be generated using solar panels or wind turbines, respectively.

## Sustainable Energy

***Sustainability*** is meeting the needs of the present generations without compromising the ability of future generations to meet their own needs. ***Sustainable energy*** is energy that is inexhaustible because its source(s) is renewable. For example, energy obtained through wind or solar energy is sustainable because wind and solar energy are inexhaustible. Harnessing these types of energy is also a relatively clean process. Additional renewable energy sources include alternative fuels, methane digesters, small-scale solar panels, wind-power turbine generators, and biomass generation, **Figure 4-13**.

### Alternative Fuels

Most fuel produced today comes from fossil fuels, such as petroleum and coal. Fossil fuels are nonrenewable resources, meaning they are in limited supply. Biofuels and hydrogen fuel cells are two alternatives being developed to lessen dependence on fossil fuels. It is important to recognize that energy is needed to produce fuels. When evaluating the viability of an alternative fuel, the energy needed to produce the fuel must be compared to the energy released when the fuel is burned.



## *Sustainable Agriculture*

### Green Building Technology

Green building technology innovations can reduce both energy costs and environmental impacts. A *green building* is designed, built, and operated using environmentally sustainable methods to minimize environmental impacts. Choosing efficient systems for heating, cooling, ventilation, and lighting reduces energy costs, minimizes pollution, and helps support the use of renewable energy on-site by cutting loads. Economic evaluation of green building technologies is highly site-specific. Their feasibility depends on variables such as electric demand (kW) and consumption rates (kWh), labor costs, and other options available for the building site.

*Consider This*

1. Are there standards for green building applications? What are they and who regulates them?
2. What types of green technology are being used in production agriculture? How does the efficiency compare to that of traditional systems?
3. What type of SAE could you have based on green technology?

> **Safety First**
>
> **Using Biofuels**
>
> Note that not all vehicles can use biofuel or biodiesel. *Always* check the manufacturer's fuel recommendations before filling a vehicle's tank.

## Biofuels

***Biofuels*** are renewable resources—they are produced from natural and agricultural products that can be replaced naturally. Fuel ethanol, a common biofuel, is an alcohol made by fermenting plant matter that is high in carbohydrates. The major feedstock used in the production of fuel ethanol is corn. Approximately 94% of ethanol is produced from the starch in corn grain. However, crops such as sugar beets or other starchy crops can be used. Ethanol is currently blended with gasoline in an effort to reduce emissions and decrease the use of nonrenewable fuels.

Biodiesel is a renewable biofuel that is used in diesel engines. It is created using a complex process called transesterification, which involves a chemical reaction between methanol (a type of alcohol) and oils from vegetables, animal fat, or recycled cooking oils. Biodiesel can be used as an additive to traditional diesel fuel or as a stand-alone alternative fuel for diesel engines.

## Electric Farm Equipment

Lithium-ion batteries and recent developments to electric motors have made it possible for start-up companies to begin producing an electrically powered tractor. Companies, like Solectrac, have begun sale and distribution of these vehicles to meet zero emissions requirements, such as those in California. This battery-powered equipment has an operating time ranging from four to eight hours, depending on the load.

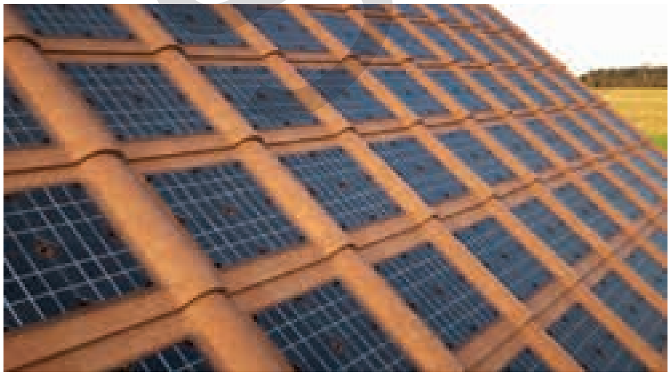
The future of electrically powered farm equipment is still developing. John Deere has been testing and developing equipment that is fully electric and autonomous. The John Deere GridCON 6120R tractor is a tethered machine that uses a cable connection from the border of the field. Whether battery powered or cable powered, electric vehicles are in the future of farming.

RikoBest/Shutterstock.com

**Figure 4-14.** Anaerobic digesters produce energy for farm operations and help reduce greenhouse gases.

## Anaerobic Digesters

***Anaerobic digesters***, also called ***methane digesters***, are growing in popularity. These digesters break down crop residue and animal manure to generate electricity or heat for farm operations. See **Figure 4-14**. Anaerobic digestion is a biological process that produces a biogas, which is composed of different gases created by the breakdown of organic matter in the absence of oxygen. Anaerobic digesters turn manure into a renewable energy source and can reduce odors and greenhouse gas emissions. However, the initial cost to install these systems is high. Farm size and access to electrical transmission lines can also limit the adoption of this technology.



Negro_Elkha/Shutterstock.com

**Figure 4-15.** A newer technology is solar shingles that can be installed to provide a solid roof with the benefit of solar energy.

## Photovoltaic Systems

***Photovoltaic systems***, or *solar electric energy systems*, convert light energy (photons) into electricity (voltage) to provide power. These systems supply power for a number of remote agricultural applications, including pumping and electric fencing. One recent development in solar panel technology is the incorporation of photovoltaic equipment into roofing products for building construction, **Figure 4-15**.

Photovoltaic systems convert the photons into direct current (DC) electricity. An inverter is needed to convert the DC power into the alternating current (AC) that powers devices such as tools and equipment that plug into an electrical outlet.

The amount of electricity generated by a photovoltaic system depends on how much of the sun's energy reaches it. Areas in the southwestern United States can use these systems efficiently because of the high availability of sunlight or peak-sun hours. The term *peak-sun hours* refers to the amount of solar insolation (the sun's radiation that reaches Earth's surface) for a particular location if the sun were shining at its maximum value for a certain number of hours. Peak-sun hours vary by season—they are highest in summer and lowest in winter. At night or on cloudy days, the system may not produce enough electricity to meet electrical needs. The average solar cell of a system is about 15% efficient in converting light energy to usable electricity. An additional concern is the limited ability to store electricity generated during the daylight hours for use at night.

## Wind Energy

Turbines in fields or on farmsteads can harness energy from the wind to generate power, **Figure 4-16**. The size of a wind turbine affects the power rating. Turbines with blades that extend the length of a football field can produce enough power for 1400 homes. Smaller turbines can generate from 50 to 70 kilowatts of power.

Sustainable wind speeds are critical for consistent and reliable electrical energy production. Wind resources are classified based on wind-power density classes. The classes range from one to seven. Class three and above are considered the most suitable for wind turbines. These areas have an average annual wind speed of at least 13 mph. The disadvantages of wind energy production include cost and the variability of wind speeds when power is at the highest demand.

Sarah Fields Photography/Shutterstock.com

**Figure 4-16.** These wind turbines are located on a cotton field in rural West Texas.



# Environmental Systems

Some of the largest annual expenses for producers include energy use in postharvest crop conditioning, crop irrigation, livestock housing systems, and greenhouses. Common agricultural structures, such as barns, grain bins, machine storage, and silos may also need support systems to provide lighting, maintain temperatures, regulate humidity, and provide adequate ventilation. The mechanical and electrical systems that furnish the ventilation, heating, cooling, and lighting functions require scheduled maintenance to maintain their efficiency and operate safely. Technologies being used in many agricultural applications include automation, energy-efficient lighting, and automatic climate controls for food storage and distribution.

## Automation

***Automation*** means that the operation of equipment, processes, or systems is automatically controlled by mechanical or electronic devices instead of manually. Automation technologies are being used to maintain tighter control over heating, ventilation, and lighting of buildings. This is accomplished through sensors and controllers that monitor and improve the efficiency of heating and cooling systems. Sensors provide the controller with data on temperatures, humidity, pressure, current flow, airflow, and other essential factors. The controller is programmed to monitor the inputs and send control commands to devices of the system.

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**Figure 4-17.** LED lighting is used in indoor growing conditions to support vegetable production. *The bulbs in this installation are different colors. Why would a grower use multiple light colors?*

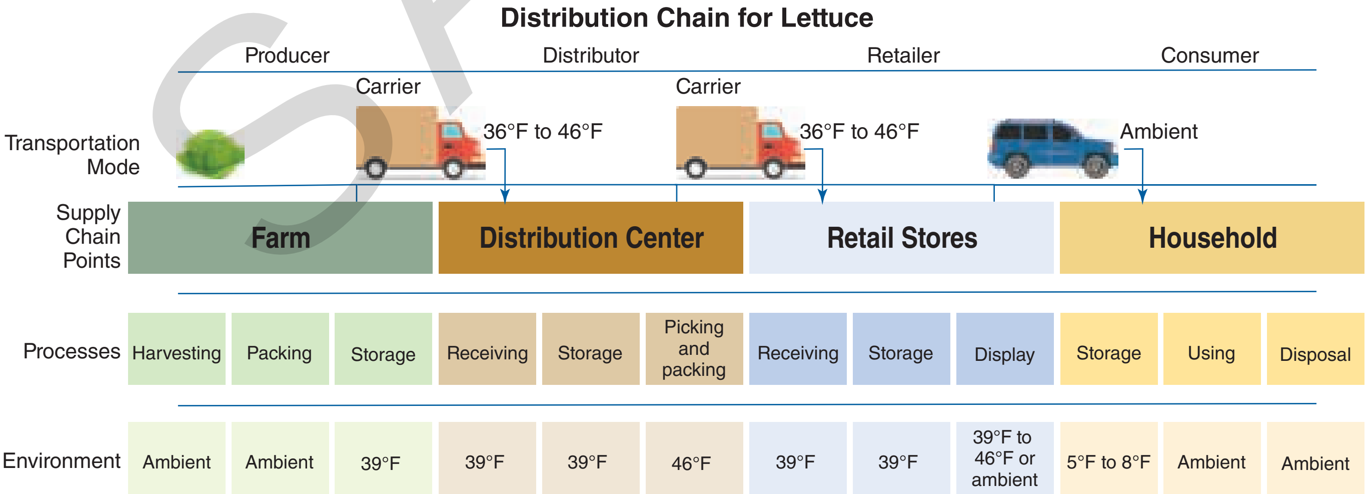
## Energy-Efficient Lighting

One of the top expenses of greenhouse production is supplemental lighting. Growers use supplemental lighting to manipulate plant growth. In order to do so, the lighting must simulate natural light in terms of quantity/intensity, length of exposure, spectrum, and uniformity. Supplementing natural light is expensive. Fortunately for today's horticulturalist, energy-efficient LEDs (light-emitting diodes) can be used in most greenhouse applications. LEDs require 75% less energy and last 25 times longer than traditional incandescent bulbs without using harmful mercury found in fluorescent bulbs. LEDs can help create indoor growing environments that supply the spectrum and intensity that fruit and vegetables need without adding extra heat, **Figure 4-17**.

## Food Distribution and Safety

There are many steps associated with food production from the farm to the table. Many of these steps provide an opportunity for the introduction of toxins or pathogens, either by accident or as a deliberately harmful act of agroterrorism. *Agro-terrorism* refers to potential terrorist attacks using the food supply. It is, therefore, critical to identify and control supply access points for disease and other biological agents along the chain of food distribution, **Figure 4-18**.

To avoid spoilage and wasting, food must be properly handled and stored, and it must be transported in a timely manner. On the farm, some produce is picked and then cooled in the field or in a storage facility to remove field heat. This cooling slows or inhibits wilting and the growth of mold or bacteria. It also reduces the production of ethylene (a natural ripening agent) or minimizes the produce's reaction to ethylene. The produce may be shipped quickly or it may be stored on the farm. Both situations require a controlled environment in which the proper temperature must be maintained.




artmakerbit/Shutterstock.com; Usman Tahir/Shutterstock.com; Vector Tradition/Shutterstock.com

**Figure 4-18.** Data management system to trace distribution of crops such as lettuce. This is useful in traceability for food safety.

Different produce requires different cooling and storage temperatures to keep it fresh and to avoid freezing or damage from the cold.

When the produce arrives at a distribution center, it may sit in storage before processing. Produce intended for fresh production is often washed before packaging. It is then stored or shipped quickly to wholesale or retail stores in a temperature-controlled environment. It will be put out for purchase or it may be stored before it is used to replenish displays. Produce intended for processing is also washed before being shipped to a processing plant, such as apples being used for apple pies, **Figure 4-19**. The produce may sit in storage or be processed quickly.

Juice Flair/Shutterstock.com

**Figure 4-19.** The mechanized washing and sorting of apples greatly increases productivity and efficiency.

As you can see, there are many points in a food production chain where food can be compromised. Contamination can be intentional, caused by an extended delay in shipping, or simply caused by failure to maintain the proper temperatures at one or more points in the supply chain. Safe handling and storage by the consumer also needs to be used to reduce contamination of foods.

Produce cooling requires energy and mechanical or electrical equipment and some of the technologies discussed in this chapter. Common methods used include room cooling, forced-air cooling, hydrocooling, top or liquid icing, vacuum cooling, and evaporative cooling.

## *Sustainable Agriculture*

### National Center for Appropriate Technology

The mission of the National Center for Appropriate Technology (NCAT), a national nonprofit agency, is to promote sustainable living. Their work in the agricultural area includes providing assistance to small farmers and beginning farmers and supplying technical assistance and information for sustainable agriculture. NCAT also supports veterans through their Armed to Farm program by offering hands-on and classroom learning opportunities.

NCAT-recommended guidelines for choosing technologies to improve efficiency and sustainability include:

- Begin with a design that is suitable for local conditions. The design should take advantage of natural ventilation, heating, and lighting.
- Use equipment that minimizes operating energy needs.
- When possible, incorporate renewable energy supplies.

*Consider This*

1. Does NCAT offer internships? If so, how do you qualify and apply for a position? How would an internship with NCAT benefit you and your career plan?
2. How can buildings be oriented to take advantage of natural ventilation, heating, and lighting?
3. How can technology enhancements build capacity of fruit and vegetable producers?

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**Figure 4-20.** Older tractors may emit excessive particulate matter and greenhouse gases during field operations.

# Pollution

Pollution is the introduction of harmful contaminants into the land, air, and water. Two major forms of pollution are air pollution and water pollution.

## Air Pollution

Air pollution results from many human practices, including manufacturing, agriculture, and the use of aerosol products. In addition, some scientists consider methane from livestock production to be a significant contributor to air pollution. However, a major cause of air pollution is vehicle emissions from internal combustion engines, particularly diesel engines, **Figure 4-20**. Manufacturers were tasked with finding technologies that reduced emissions but did not reduce performance or gas mileage. Vehicle emission reduction and control technologies include engine control units (ECUs), exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and performance improvements such as forced induction.

### Engine Control Units

Computers are used to help make internal combustion engines more efficient. These computers, commonly called ***engine control units (ECUs)***, are used in combination with a network of sensors and actuators to monitor and control various engine functions, fine-tuning the engine for greater fuel efficiency and increasing overall power.



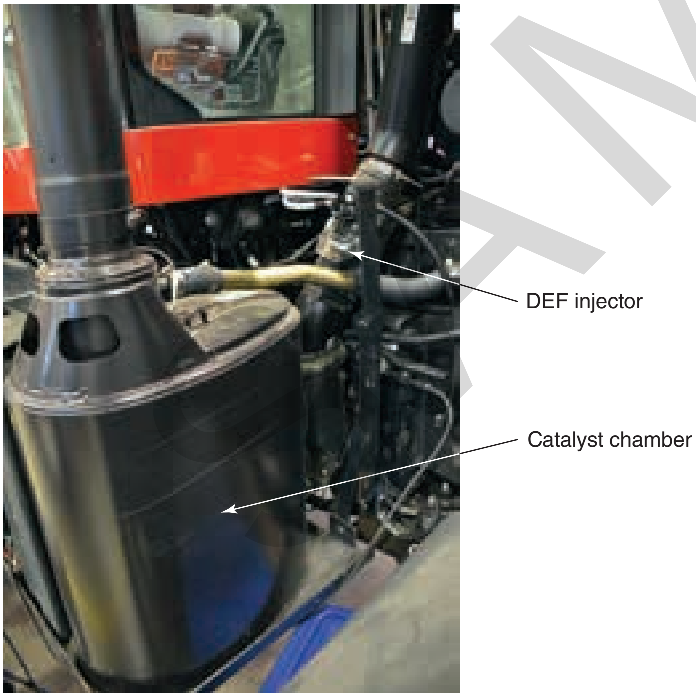


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**Figure 4-21.** Selective catalytic reduction (SCR) systems are used to help reduce diesel engine emissions. Diesel exhaust fluid (DEF) is injected through a special catalyst into the exhaust stream of a diesel engine to break down $NO_x$ emissions into nitrogen and water.

### Exhaust Gas Recirculation

***Exhaust gas recirculation (EGR)*** allows cooled exhaust gases to be drawn into the air-fuel mixture entering an engine's cylinders. EGR reduces combustion temperatures, resulting in lower nitrous oxide emissions. Nitrous oxide is a major component of smog. EGR also improves fuel economy. The lower temperatures also help to avoid heat transfer energy losses, meaning that more of a tractor's energy is directed to providing power for its wheels. Combined with electronic fuel injection, these technologies have created more efficient and cleaner-burning engines.

### Selective Catalytic Reduction

***Selective catalytic reduction (SCR)*** is a recent technological development that reduces diesel engine emissions. A liquid reducing agent is injected through a special catalyst into the exhaust stream of a diesel engine to break down dangerous $NO_X$ emissions into harmless nitrogen and water. Automotive-grade urea (made of synthetic ammonia and $CO_2$) is commonly used as the reducing agent and is sometimes referred to as ***diesel exhaust fluid (DEF)***. See **Figure 4-21**.

## Forced Induction

***Forced induction*** is the delivery of compressed air to the intake of an internal combustion engine. Turbochargers and superchargers increase the air pressure entering the engine. Forced induction makes higher power possible with smaller engines, improving fuel economy. See **Figure 4-22**.

## Water Pollution

Safe, clean drinking water is essential for life. Water pollution may be obvious, such as debris and contaminants in lakes and streams. However, pollution of groundwater is usually less obvious. Water that looks clear and clean can contain toxins.

Sources of water pollution from human activity include sewage systems, agricultural runoff carrying pesticides and fertilizers, factory wastewater, plastics, oil from petroleum spills, sediments from construction activity, and thermal pollution from factories. Efforts are underway to reduce the impact of manufactured pollutants to the water supply. Alternative sources of energy can reduce water contaminants. Continued development of technologies to treat contaminated water is necessary for future clean water.

Sewage treatment is subject to local, state, and federal regulations and standards. Modern sewage treatment facilities have advanced well beyond the historical practice of dumping raw sewage into rivers and oceans. Using multistep processes involving primary, secondary, and additional treatments, modern facilities disinfect sewage-contaminated water so it can be introduced directly and safely into the environment.

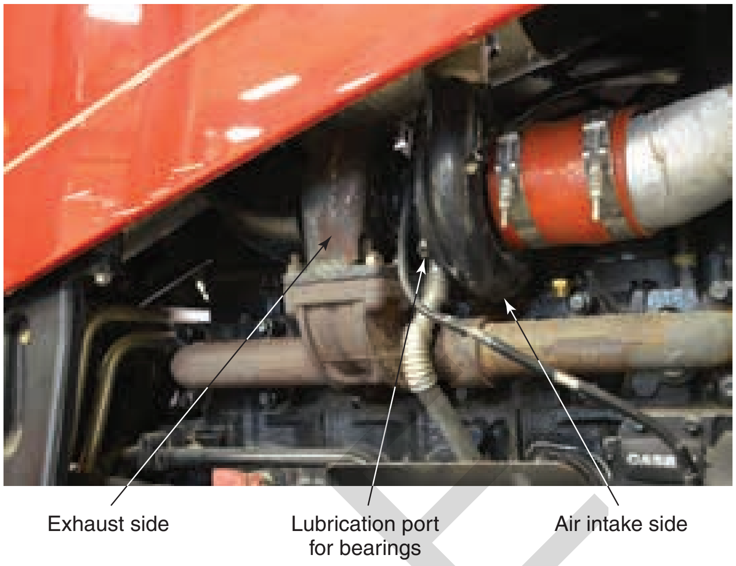


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**Figure 4-22.** Forced induction systems, such as this turbocharger on a tractor engine, increase the air pressure entering the engine, increasing power and boosting fuel economy.



### *Career Connection*

#### Field Scout Technician

Field scout technicians inspect and record crop performance as well as observe pests affecting crop performance. The data gathered is often georeferenced and mapped using GIS to facilitate site-specific management decisions. Farmers who do not have the equipment or skills hire technicians to collect data that can be used with their tractors and GPS.

This career requires knowledge and skills relevant to GPS software and other technologies such as UAVs. Knowledge of aerial photography and imaging technology are essential for field scout technicians. Good communication skills are also needed, as reports must be shared with clients and other interested parties. Education requirements beyond high school may range from a technical certificate to a four-year degree from a university. Annual salaries for this career range from $34,000 to $79,000.

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# Chapter 4 Review and Assessment

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## *Chapter Summary*

- Precision agriculture technologies can be used to manage the application of nutrients and water within a field based on various information sources.
- In geographic information systems, data is referenced with GPS coordinates and then mapped to create management zones or grids that are used for making production decisions.
- Agricultural drones, or unmanned aerial vehicles, are being developed to aid in crop and livestock management.
- Biotechnology has enabled advances in crop varieties to withstand damage from pests and diseases as well as increase nutritional value of a crop. This has resulted in higher production yields while minimizing the use of pesticides resulting in a healthier, safer food supply.
- Genetic engineering introduces traits that do not naturally occur in a species. Traits introduced in crops include pest resistance, disease resistance, drought resistance, spoilage resistance, and chemical resistance.
- Several alternative electricity generation technologies, such as wind power, biological energy sources, and anaerobic digesters, can meet the energy demands of farming operations and reduce costs.
- Alternative fuels such as biofuels and hydrogen fuel cells are being developed to lessen dependence on fossil fuels.
- Safe handling and packaging methods must be adapted to reduce food contamination as methods of production and processing change to meet increasing demands.
- Vehicle emissions are a major cause of air pollution. Vehicle emission reduction and control technologies include engine control units (ECUs), exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and forced induction.

## *Vocabulary Review*

Match the vocabulary terms listed in the *Words to Know* to the correct definition.

A. anaerobic digesters
B. as-applied map
C. base station
D. biologging
E. diesel exhaust fluid (DEF)
F. differential correction
G. drone
H. engine control unit (ECU)
I. exhaust gas recirculation (EGR)
J. forced induction
K. genetic engineering
L. geographic information system (GIS)
M. global positioning system (GPS)
N. precision agriculture
O. rover
P. selective catalytic reduction (SCR)
Q. sensor
R. site-specific management
S. soil compaction
T. soil conductivity
U. soil nutrients
V. soil pH
W. sustainability
X. sustainable energy
Y. technology
Z. telematics
AA. thematic map
BB. variable-rate technology (VRT)
CC. yield map
DD. yield monitoring

1. A computer used on vehicles to help make internal combustion engines more efficient by monitoring and controlling various engine functions.
2. A device that detects or responds to physical stimulus and transmits an impulse to provide data or operate a control.

3. The use of wireless sensor networks to record multiple animal health variables.
4. A digital representation of a field that serves as a historical record of the application rate of a product, such as a pesticide.
5. Technology that integrates wireless telecommunications with information technology to enable long-distance transmission of information in real time.
6. Energy that is inexhaustible because its source(s) is renewable.
7. Microorganisms that break down crop residue and animal manure to produce a biogas that can be used to generate electricity or heat.
8. A measure of the soil's density.
9. The ability to meet the needs of the present generations without compromising the ability of future generations to meet their own needs.
10. The application of science to solve a practical problem.
11. A digital representation of the high and low productive sections of a field.
12. A digital representation that provides information about a topic or theme, such as population density or soil type.
13. A measure of the soil's ability to hold and make water available to the plant.
14. A navigation system made up of a network of satellites in orbit around Earth that transmit signals used by GPS receivers to pinpoint their exact geographic location.
15. A reducing agent for selective catalytic reduction that consists of automotive-grade urea (synthetic ammonia and $CO_2$).
16. A stationary GPS receiver that serves as a location with a known latitude/longitude through which differential corrections can be made to provide accurate locations in the field.
17. A systematic approach to site-specific agricultural management in which variations in crop growth are observed and recorded and the data is used to improve productivity.
18. A technique used to increase the accuracy of the GPS signal.
19. A mobile GPS device.
20. A technology in which a liquid reducing agent is injected into the exhaust stream of a diesel engine to break down nitrous oxide into harmless nitrogen and water.
21. A technology that allows farmers to vary the rate of crop inputs based on precision agriculture methods and site-specific needs.
22. The use of sensors to measure and record data about moisture and other conditions during harvest.
23. An aircraft that is controlled remotely and does not have a human pilot.
24. Data management software used to map, model, query, and analyze large quantities of data within a single database according to a reference location.
25. Observing and measuring the differences in identified locations within fields and using this information to manage improvements according to individual needs.
26. The delivery of compressed air to the intake of an internal combustion engine, making higher power possible with smaller engines and improving fuel economy.
27. The indication of a soil's acidity or alkalinity, which is measured by the concentration of hydrogen ions in the soil.
28. The process of drawing cooled exhaust gases into the air-fuel mixture entering an engine's cylinders to reduce combustion temperatures, which results in lower nitrous oxide emissions.
29. The scientific process of making changes to the genetic code of plants or animals to produce a desired trait.
30. The substances or elements that plants need to grow and thrive.

## *Know and Understand*

Answer the following questions using the information provided in this chapter.

1. The Industrial Age, the technology age, and the _____ age have brought technological advances to the agriculture industry.
   A. information
   B. precision
   C. climate
   D. fertilizer
2. What precision agriculture technology allows the user to vary the number of seeds planted based on GPS field data?
   A. Georeferenced information system
   B. Yield monitoring
   C. Variable-rate technology
   D. SMART water
3. _____ is a software system used to map, model, query, and analyze large quantities of data within a single database according to a reference location.
   A. A global positioning system (GPS)
   B. A geographic information system (GIS)
   C. Variable-rate technology (VRT)
   D. Site-specific management
4. *Drone* is another name for a(n) _____.
   A. unmanned aerial vehicle
   B. robot
   C. GPS
   D. hydrogen fuel cell
5. Which of the following is an example of biotechnology?
   A. Herbicide-resistant soybeans
   B. Exhaust gas recirculation valve
   C. Geographic information system
   D. Biologging
6. *True or False?* Genetically modified crops are agricultural plants in which the stem of one plant is attached to another plant's roots.
7. Which of the following is a benefit of green construction?
   A. Efficient temperature control and lighting systems reduce energy costs
   B. Minimizes pollution and uses renewable energy
   C. Minimal environmental impact
   D. All of the above.
8. Which of the following is not considered a source of sustainable energy?
   A. Wind
   B. Solar
   C. Hydroelectric
   D. Diesel fuel
9. Which of the following is considered an alternative fuel source?
   A. Biodiesel
   B. Gasoline
   C. Liquid propane
   D. Diesel
10. Which of the following is the primary source for ethanol fuel?
    A. Soybeans
    B. Corn
    C. Manure
    D. Gasoline
11. The source of power for a photovoltaic system is _____.
    A. wind
    B. crop residue
    C. the sun
    D. a generator
12. A(n) _____ is needed to convert DC power generated by solar panels into alternating current.
    A. inverter
    B. wind turbine
    C. transformer
    D. light-emitting diode
13. Which of the following is an example of water pollution?
    A. Runoff from a dairy barn
    B. Dumping pesticides into a ditch
    C. A broken septic system for a farmhouse
    D. All of the above.

14. List three benefits of exhaust gas recirculation (EGR) and diesel exhaust fluid (DEF).
15. Explain three ways to manage agricultural technology to reduce harmful impacts on the environment.

## *Analyze and Apply*

1. Fields with varying soil profiles often have areas that underperform despite high amounts of irrigation. Explore how various-sized tubing or nozzle diameters can be used to design a variable-rate irrigation system. Determine how accurate your design is by recording the amount of water that is collected from each opening/tubing. Discuss if your design was successful and how you might improve your design.
2. Plant cover, distribution, and species composition of a field are important factors in managing a crop or pasture for weeds. By understanding variability within a field survey, you will be able to provide site-specific recommendations to target problem areas that meet the economic threshold for application of a pesticide. Develop a quadrant technique to measure plant distribution for a lawn or pasture. Determine density and composition. Make a recommendation based on findings from mapping the lawn and pasture. Determine if spot treatment or a broad application would be worth the investment.
3. Aerial imaging of land can provide visual indicators on crop health or areas of damage caused by pests. A variety of imaging options are available at varying price points. Research and compare visual imaging options for use in crop production. Identify the costs and potential benefits of implementing this technology. Develop a poster to present your findings and discuss with your class.

## *Thinking Critically*

1. Research information on genetic modification of crops for human consumption. Find sources that support GMO use and sources that oppose it. Write a report detailing your findings and include your personal opinion.
2. What forms of pollution are generated by the agricultural industry? What greenhouse gases are emitted? In what ways can agricultural producers limit pollution and the emission of greenhouse gases? Write a report or create a video that answers these questions.
3. What is your vision of the future of farming? What technological innovations do you think will be most important in meeting agricultural challenges in the next 50 years? Be prepared to answer these questions in class.

## *STEM and Academic Activities*

1. **Science**—Develop an experiment to determine the effect of variables on the accuracy of handheld GPS receivers. For example, trees and buildings can interfere with the signal reception. Graph your data and write a report that details your findings. Explain the importance of an accurate GPS signal.
2. **Technology**—Compare and contrast two software programs used for GIS mapping. Write a report that details your findings. Explain which program you would prefer to use and why.
3. **Math**—Develop a spreadsheet that compares the costs of using three different GPS guidance systems for tractors. Your spreadsheet should include software subscription fees, installation costs, and hardware costs.

4. **Language Arts**—Read an article in a farming or ranching magazine that discusses a new trend in agricultural technology. Write a summary that identifies the applications of this new technology, as well as the pros and cons of adopting the technology.
5. **Social Science**—Research several types of agricultural robots that have been developed in the past few years. What jobs will these robots displace? What types of jobs will the increasing use of agricultural robots create?

## *Communicating about Ag Mechanics*

1. **Reading and Writing**—The use of telematics raises ethical and security concerns for many users. Some producers are concerned that their real-time harvest data may be acquired by competitors and used to influence market speculation. There is also a concern for the loss of privacy. What is your opinion on this matter? Write a position paper and support your work with facts obtained from reliable resources.

## SAE *for* ALL *Opportunities*

1. **Immersion: Research SAE**—Investigate electric vehicles and their application to agriculture. Research potential cost and savings by implementing an electric vehicle over a diesel fueled vehicle.
2. **Foundational: Intermediate SAE**—Complete an investigation on educational and training requirements needed for an agricultural engineer. Determine post-secondary institutions that provide opportunities for education in the field of agricultural engineering and computer science.
3. **Immersion: Research SAE**—Develop a prototype of an electric tractor to simulate an agricultural application to evaluate the feasibility for implementation

## SAE *for* ALL *Check-In*

- How much time have you spent on your SAE this week?
- Have you logged your SAE hours?
- What challenges are you having with your SAE?
- How can your instructor help you?
- Do you have the equipment you need?