Chapter 1

1. What are two site-specific management strategies that can be implemented with the goal of increasing profits?
   a. Increasing yields with the same level of inputs, simply redistribution (p. 3)
   b. Targeting inputs to where they are needed (p. 3).
   c. Improving crop quality (p. 3)

2. What are three questions that a farmer must answer before adopting precision farming?
   a. How do crops, soil, and environmental characteristics vary spatially and temporally?
   b. Does variation affect crop yields and/or crop quality?
   c. What are your short and long term goals?
   d. Do I have the needed resources to implement precision agriculture?

3. What are the six primary tools of precision farming?
   a. Global navigation satellite system (GNSS),
   b. Yield monitors and digital mapping software,
   c. Soil sampling and variable rate fertilizer application,
   d. Remote sensing,
   e. Geographic information system (GIS),
   f. Data management,

4. Define spatial variability
   a. Spatial variability is the variation in the crop, soil, and environmental conditions over distance and depth.

5. Define temporal variability.
   a. Temporal variability is the variation in the crop, soil, and environmental conditions over time.

6. Develop a strategy to determine the yield limiting factor (pg. 10)
   a. Convert the data to relative yield maps, take measurement, create and inspect the maps, and identify similarities and differences. Determine the similarities and differences between yields and other measurements. Ground truth remotely sensed data. Remember that correlation between yields and soil parameters does not mean causation. Augment this information with local knowledge and on-farm testing.

Chapter 2

1. Describe how soil erosion creates variability in crop grain yields.
   a. Soil erosion has removed highly productive surface soil from the soil profile. A detailed discussion is available on page 18.

2. What technology enables inexpensive and rapid mapping of spatial variability.
   a. GNSS or GIS, GPS,

3. What is the source of anthropogenic variability?
   a. Man-made differences

4. Provide an example on how pests create variability and identify a management practice you might use to address that variability.
   a. Biotic stress to crops is caused by living organisms that reduce yields. The yield reductions are not uniform across a field but are often located at specific locations. Biotic stresses are influenced by weather variability.

5. What does the term “E_{ST}” in the G × E_{ST} × M
represent?

a. (E) represents environment as impacted by spatial (S) and temporal (T) factors

6. Name two examples of biotic factors that cause variability within crop production fields.

a. Living organisms (biotic) such as pathogens, insects, nematodes, and vertebrate animals can reduce yields by feeding on the crops.

b. Weeds can reduce yields by competing with the plant for resources.

Chapter 3

1. What is the minimum number of satellite signals needed for a GNSS receiver to compute a 3-dimensional position? Explain.

a. Four satellites is the minimum required for complete position determination, but most receivers will utilize more than four satellite signals simultaneously if they are available. Some receivers will acquire a fix with only 3 satellites, but it will only be a 2-dimensional fix.

2. Use internet resources to explore the status of the GPS constellation and report the total number of satellites currently functional in the constellation, how many have L2C capabilities, and how many broadcast the L5 codes.

a. The answer will vary with time. See https://www.gps.gov/systems/gps/space/ and https://www.navcen.uscg.gov/?Do=constellationStatus

3. Use internet resources to explore the CORS stations in your state. Print a state map showing all of the locations. For the one closest to your location, find out where it is and when it was established.

a. https://www.ngs.noaa.gov/CORS/ for more information

4. A farmer wants to purchase an RTK GNSS system for a farm. The base station antenna will be placed on the top of a centrally located grain bins. If the accuracy of the RTK GNSS system is 1.5 cm + 4 ppm, what is the accuracy at a field located 35 km away?

a. The 4 ppm accuracy value means that for each 1,000,000 meter from the base station, accuracy decreases 4 meter. 35 km * (1000 m km⁻¹) = 35000 m of baseline separation

Degradation = 35000 m * (4 m/1,000,000 m) = 0.14 m = 14 cm.

Accuracy = 1.5 + 14 = 15.5 cm

5. For a particular date and location, use a constellation modeling tool to plot the availability of GPS and GNSS satellites and the DOP values. Are there particular times of the day that would be really good or potentially bad for GNSS work?

a. See page 28

6. Explain how absolute and relative accuracy of GNSS receivers would affect their use in machine guidance applications.

a. A receiver with a good relative accuracy would exhibit consistent position determination relative to earlier position solutions from that same receiver. That receiver might be very adequate for providing position solutions for vehicle guidance systems if the end result was simply to reduce the amount of overlaps and skips in a single field operation. If, however, it would be desirable to use multiple machines in the same field, or overlay data from one field operation with another, the lack of absolute accuracy could cause significant spatial offsets between the field operations. The absolute accuracy of a receiver is a quantification of the position deviation from some established reference frame. A high absolute accuracy would ensure that multiple machines working in the same field would be able to follow the same path, and that multiple data layers would overlay correctly without geographic offset.

7. Why would an accuracy test for a GNSS receiver that lasted for 1 hour not be a good indication of the performance of the receiver?

a. Another critical aspect of GNSS position quality is short-term versus long-term accuracy. Because most GNSS satellite constellations are constantly changing, GNSS position measurements tend to drift with time. Consequently, position measurements taken within a shorter time will tend to be more precise than points collect-
ed over extended time periods. Because of this, many manufacturers will quote a short-term accuracy performance parameter often called “pass-to-pass” accuracy. This is typically based on a 15-minute relative accuracy performance. For many receivers, the long-term accuracy is approximately 3 times larger than the short term “pass-to-pass” accuracy.

8. A farmer has a field that is bordered on one side by a large manufacturing facility that is in a three-story metal-clad building. Why might their GNSS equipment perform poorly near that edge of the field?

a. Multipath errors occur when the same radio signal is received at two different times. This will happen when the radio signal bounces off of some object. For example, a GNSS transmission could come straight to the receiver and also bounce off of a building causing the same signal to arrive at the receiver a short time after the initial receipt (Fig. 3.6). Multipath errors can cause significant problems with GNSS receivers especially when operating around objects that reflect radio waves such as metal buildings and bodies of water. Placing the receiver antenna near any metallic objects increases these risks. Multipath error occurs when the signal bounces obstructions before it reaches the receiver. Manufacturers effectively use choke rings in antennas and other hardware and software filtering techniques to minimize the effects of multipath errors, but the user should still be careful to scrutinize GNSS information when operating in places where multipath is a potential.

9. A GPS satellite is at an altitude of 20,100 km directly above a receiver. Calculate how many wavelengths of the L1 and L2 GPS frequencies there would be between the satellite and the receiver.

a. The L1 band operates at 1575.42 MHz and L2 operates at 1227.60 MHz. One hertz (Hz) means that an event repeats once per second. In the case of radio waves, a (Hz) is interpreted as a (wave per sec)
   i. The speed of light is 299,792,458 m s⁻¹ which is approximately equal to 300,000,000 m s⁻¹.
   ii. Speed of light (C) = wavelength × frequency

   i. 1 MHz = 1,000,000 Hz = 1,000,000 wave/sec
   iv. L1 wavelength = (300,000,000 m s⁻¹)/(1,575,000,000 wave s⁻¹) = 0.19 m per wave
   1. Number of wavelengths = 20,100,000 m/0.19 m/wave = 105,525,000 waves
   v. L2 wavelength = (300,000,000 m s⁻¹)/(1,227,000,000 wave s⁻¹) = 0.2445 m per wave
   1. Number of wavelengths = 20,100,000 m/0.2445m/wave = 8,220,900 waves

10. A farmer in Canada is getting ready to plant a field that is perfectly square and nearly completely flat with a GNSS-based autosteer system. Which direction (N-S or E-W) should they plant the field to get the best guidance accuracy? Explain your reasoning.

a. As shown in Figure 3.9, satellites do not cross the poles of the earth. In Canada, which is relatively close to the north pole, there will be less satellites visible to the north. For best accuracy based on satellite configuration, it is desirable to have satellites spread evenly in all directions from the receiver. When traveling N-S in Canada, there is a good chance that there will be satellites evenly distributed to then left and right of the receiver giving good accuracy in the lateral direction, which would be good guidance accuracy. When traveling from E to W, for example, there will be fewer satellites on the receivers right side, which could reduce the lateral guidance accuracy. Therefore, from a purely guidance perspective, the receiver would be expected to perform better with N-S rows than with E-W rows.

Chapter 4

1. Describe in your own words the characteristics of the two components of a GIS: Map and Attribute Table.

a. Attribute tables are the result of query, and they may contain a wide of information and it places the data into rows (records) and columns (fields).

2. Several examples of GIS are provided within this chapter. Find and research two GIS not listed and
describe their characteristics and functions.

3. In mapping a fenceline around a field, it is most appropriately done as a line feature. Discuss if you agree or disagree with this statement and provide justification for your position.

   a. Point features represent those objects in which the location alone is needed. Lines represent those objects which the location and length is needed. Polygons are used to represent objects in which location and area are needed. In agriculture, a fence line could represent the field boarder, because it defines outer borders of the production area. Depending on purpose, the fence line could be represent by a line or polygon.

4. An example of an attribute data is zip code such as 93210. What type of data is this?

   a. A zip code represent a point features in which the location alone is needed

5. Using a paper map, determine the GPS and UTM coordinates of your current position. Confirm with GPS or your instructor

   a. “Hard Copy” is used to reference printed materials or resources that a person can touch and hold. Examples are paper maps (Fig. 4.12), atlases, or paper road maps. “Digital” refers to data, materials, resources and other things that are in an electronic format used in a computer. Digital maps (Fig. 4.13) are viewable and created on a computer.

   b. GPS information provides Latitude and longitude information. This information is provided in degrees/minutes/seconds. Latitude is an angle that ranges from zero at the equator to 90 degrees at the north and south poles. Longitude is the east-west position relative to Greenwich England.

   c. UTM consists of 60 separate Transverse Mercator projection. In UTM, value is comprised of a zone number, hemisphere, and easting and northing referenced to the central meridian in each zone.

6. This chapter lists several examples of agricultural data layers, there are many other specific examples. List 5 other specific data layers that could be collected for an agricultural field.

   a. A data layer is a geographic representation of a specified type of object. All real-world objects can be mapped as a feature within a data layer. A data layer is a geographic representation of a specified type of object. All real-world objects can be mapped as a feature within a data layer.

7. Explain the difference between the GIS tools’ “field calculator” and “raster calculator”.

   a. The term “field calculator” does not refer to an agricultural field, but rather a tool within a GIS for completing calculations using the attribute fields within a GIS table (Fig. 4.41). Field calculators extend the capability of the GIS to use attributes to calculate new data.

   b. The raster calculator (Fig. 4.47), since there is only one attribute value within cells of a raster data layer, is used to create mathematical formulas using one or more raster data layers. A raster calculator provides a lot of flexibility and new data values that can be created.

8. A grower wants to know economic justification for using a new soil amendment product. What data would be needed and how could a GIS be used to determine this?

   a. There are many factors that can impact yield: crop rotation, soil types, tillage practices, fertilization, seed, and irrigation, among others. Statistical analysis of on-farm research can help define interrelationships between these parameters, or determine if two treatments are different. Based on treatment differences, the economic benefit of the proposed treatment can be tested.

   b. Yield maps provide information necessary to calculate total income. If costs were consistent through the field, there would not be a difference from the yield map. But with variable rate application and other precision agriculture tools, costs are not consistent across the field. A net profit map combines both income and expense maps to show which areas of the field are actually profitable.

9. Research examples of FMIS that provide: a) sales support; b) communication; and c) qual-
ity assurance. Give a brief description of each.

a. FMIS is farm management information system. See page text book for more information.

Chapter 5

1. What sensors need to be calibrated when preparing to harvest a field?

a. The accuracy of the calculated yield is dependent on the calibration of the moisture and mass or volume sensors, and the accuracy of the differential global positioning system receiver (DGPS).

2. What factors influence calibration constants?

a. Systematic errors are produced by using old calibration data. With time, calibrations can change due to machine wear or sensor output drift. To minimize these errors, routine calibration is recommended.

3. You harvest a 50,000 lb of corn from a field containing at 22% moisture. How many pounds and bushels of corn do you have at 15.5% moisture?

\[
a. \frac{(100\%-22)}{(100\%-15.5)} \times 50,000 = 46,153 \text{ lb corn}
\]

\[
b. \frac{46.153 \text{ lb corn} \times \text{bu}}{56 \text{ lb corn}} = 824.2 \text{ bushels}
\]

4. What will happen to the yield monitor data when the combine slows down? What happens when the combine speeds up?

a. When a yield monitor slows down, yields increase and when it speeds up yields decrease.

5. Why does yield monitor data need to be cleaned?

a. Yield monitors create files containing large amounts of spatial information including, the type of monitor, longitude, latitude, field name, object ID, Track, Swath Width, Distance, Elevation, Header Switch Status, GPS Differential Status, Time, Y and X Offset, Material Flow rate, harvester speed, productivity (acre hr⁻¹), grain moisture content, type of crop harvested, and date. However, prior to the use of the data, the erroneous data must be removed. Erroneous data is collected when the combine slows down or speeds up, as well as in the end rows. For example, if 10 bushels of grain moves from the grain auger trough by the clean grain elevator, and the combine covers 0.1 acre, then the yield is 100 bu acre⁻¹.

Chapter 6

1. How might field topography influence soil nutrient variability?

a. Within fields, topography influences crop productivity and nutrient availability to crops. The obvious affect is the thickness of A-horizon (the organic rich layer at the soil surface. The water table is generally closer to the surface, in depressions, since water runs downhill from summits to toeslopes. In addition, depressions receive not only rain water and snow melt from the atmosphere, but runoff from neighboring landscape positions. As a result, plant growth is a maximum in most years, and decomposition is minimized due to more reduced oxidizing environment compared with other landscape positions. Excessive rainfall at ridge tops, hilltops and slopes does not have time to percolate into the soil except in the sandiest-textured soils, resulting in less plant and/or crop growth and less chance for organic matter accumulation. The upper landscape positions are also subject to stronger oxidizing conditions as compared with those in depressions.

2. Name four factors other than topography that might influence natural soil nutrient variability.

a. Inherent differences produced during soil development, the result of erosion following tillage, salinity, and systematic errors from uneven application of fertilizers and manures.

3. Name two factors that might contribute to systematic variability of soil nutrients.

a. Application of fertilizers and manures can result in systematic variability (Fig. 6.4). Systematic variability is non-natural soil variability due to the activities of human. Examples of systematic variability are application of fertilizer and/or manure either too close, resulting in increased nutrient
content in strips in the direction of travel, and application of fertilizer and/or manure too far between passes, leaving untreated strips of soil between wider strips of applied nutrients.

4. Fields where high rates of phosphate and potash fertilizer were applied in a soil test buildup program would benefit from which site specific soil sampling strategy for P and K: grid or zone?

   a. The grid sampling philosophy is based on the assumption that nutrient levels are random, unrelated to anything in nature, and should be sampled without any sampler bias toward where to place the sample locations. A concept behind zone sampling, it is based on prior collected information the field can be separated into areas that have similar characteristics. The zone sampling philosophy assumes that nutrient levels and the patterns in which they appear in a field are the result of some logical reason. Grid sampling is used and preferred in regions where past fertilization or manure application has been high.

5. Name four possible tools that might be utilized to help delineate soil nutrient zones.

   a. A number of tools are available to delineate nutrient management zones: topography, satellite imagery, aerial imagery, soil electrical conductivity (EC) sensors, soil electromagnetic sensors (EM), and multi-year yield maps (Franzen, 2008).

6. What soil sampling strategy is used most often to avoid systemic soil sampling errors and why is it more effective than other strategies?

   a. Grid soil sampling include random (Fig. 6.5), random cluster (Fig. 6.6), systematic (Fig. 6.7), staggered start (Fig. 6.8), and systematic unaligned (Fig. 6.9). The systematic unaligned grid was made practical through a combination of GPS and field software that would allow random grid locations within a systematic grid. This approach minimizes the effects of systematic errors in two directions.

   Chapter 7

1. What are major crops and pests in your region?

   a. When identifying pests we recommend that you contact local experts. For these pests, when are they present and what levels of infestation are needed to cause damage?

   b. Is there GDD information about the pest development?

      i. Some information is available see suitable time to examine infestations and infections. However, little information is available for different pests.

   c. What methods are available to you to evaluate the areas of infestation?

      i. Correct pest identification (Fig 7.4), scouting (Fig. 7.1), remote sensing (Fig 7.3), and evaluate the extent of the damage, soil sampling, sweep nets, sticky traps, and leaf examination.

2. Describe the different scouting methods used for ground dwelling vs. flying insects.

   a. When scouting the first step is visual observe the area. All pests require different methodologies. Pest insects are often difficult, but not impossible, to manage because of the distribution and life stages (egg, immature, and adult) that can vary spatially within and among crop fields, as well as over the growing season. For precision agriculture decisions, we need to be able to estimate the density of insects and have an established threshold for control measures. Because most adult insects (e.g., corn rootworms) can fly, they are usually captured with sticky traps or pheromone traps laid out in a grid. Ground dwelling insects can be trapped by soil sampling setting up traps where the insects fall into a storage container.

   b. Some insect pests, such as the many aphid species, feed above ground but are not active flyers. Aphids may be dispersed by wind currents from more southern latitudes (e.g., cereal aphids) or overwinter in adjacent habitats (e.g., soybean aphids) (Parry, 2013; Severtson et al., 2015). Depending on the crop, these pests may be systematically sampled with sweep nets or whole plant counts. Plant counts are
often used to estimate densities of stalk and stem boring insects in crops, such as mature corn, where sweep nets are ineffective. Some pests live below ground, whether for their whole life or during particular life stages and their densities can be estimated with soil samples (Park and Tollefson, 2005). Soil samples are generally taken only once during a growing season, whereas other sampling methods may require sampling periodically throughout the growing season.

c. How would the methods differ for pathogens and weeds?

i. The ground crop scouting method for weeds and diseases is to walk or drive a four-wheeler in a ‘W’ pattern, or grid sample or sample based on field topography, (usually selected in advance) throughout the field (Fig. 7.1). These methods should include multiple stops at different locations to examine the area for nutrient deficiencies, water or drainage problems, wind/hail damage, weeds, insects, pathogens, rodents, deer, and nematodes. To assess changes in the problem and extent of the problem the location should be identified.

3. A producer brings in a remote sensed image of his field that matches Fig. 7.3. Develop two site-specific herbicide application prescriptions. Would you choose different herbicides or rates for different areas? Are there areas that could be left untreated?

a. When the pest problem has been correctly identified and if the pest requires treatment, the next step is to apply corrective measures to these areas in a timely manner. This requires that a treatment map be created. A map of the field and the areas to be treated needs to be developed. In some instances, the entire field may be the area of treatment. In other cases, the treatment areas may be targeted to specific areas

i. The first prescription is for a post-emergence application timing to be applied.

ii. The second prescription is for a pre-emergence application to be applied at or just before planting next season.

b. When would you suggest scouting should be done and how would you scout?

i. The scouting should be matched to the pest biology and lifecycle, the pesticide label, and characteristics of the problem.

Chapter 8

1. What portion of the electromagnetic spectrum constitutes the visible range (to the human eye)?

![Diagram of the electromagnetic spectrum]

The visible portion of the spectrum ranges from 400 to 700 nm.

2. Provide a definition of ‘vegetation index’.

a. Vegetation index is a spectral transformation of at least two bands that are designed to improve our understanding of the plant system. Indexes allow for reliable spatial and temporal intercomparisons of terrestrial photosynthetic activity and canopy structural variations.

3. Differentiate ‘remote’ sensing from ‘proximal’ sensing.

a. Remote sensing is the act of monitoring an object without direct contact. In proximal sensing the sensors are placed very close to the target. They could be in physical contact with the target.

4. A(n) __active________ sensor produces its own energy for sensing.

5. What is the principle wavelength range for thermal infrared sensing?

a. There are specific “atmospheric windows” where remote sensing is possible, but, unfortunately, there are also many areas of the spectrum where remote sensing is not possible. An example is the thermal infrared, where detectors sensitive to energy with wavelengths between 3000 and 5000 nm, and also 8000 and 14000 nm.
6. Which remote sensing platform is best suited to coverage of many square miles on a weekly basis?
   a. See Table 8.1

7. The following sensors have different resolution: one sensor detects in the wavelength range of 700 to 800 nm, another sensor detects in the wavelength range of 700 to 720 nm.
   a. A hyperspectral sensor has many narrow bands, whereas a multispectral scanner has fewer broad bands.

8. A healthy plant typically reflects more light in the visible waveband, and absorbs more in the visible waveband.
   a. A healthy plant absorbs more in the visible wavebands and reflects more in the near infrared wavebands.

9. The most commonly known vegetation index, the Normalized Difference Vegetation Index, uses reflectance in _____red______ and _____NIR______ wavebands.

10. Which remote sensing platform can be readily deployed on a short notice for crop scouting?
    a. UAV.

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**Chapter 9**

1. What is the difference between proximal and remote sensing?
   a. In proximal sensing, the instrument is placed within 2 m of the target.

2. Which sensor systems are called “on-the-go”?
   a. In terms of sensor deployment, conducting on-the-go measurements while traveling across the landscape, represents the ultimate solution and produces a large amount of information that can be used to apply a precision treatment according to a predefined algorithm.
   b. Naturally, on-the-go sensors can be moved across the field using a tractor, all-terrain vehicle, pickup, planter, sprayer, or combine. These systems can record yields, crop and soil properties as well as field elevation, when using high-accuracy global navigation satellite system (GNSS) receivers. Although on-the-go soil sensors are designed to provide information pertaining to different soil depths (layers), there is a family of instruments developed to provide detailed information at a specific field location or for an entire soil profile.

3. What measurement methods can be used to map apparent soil electrical conductivity?
   a. Electrical and electromagnetic sensors use electric circuits to measure the capability of soil to conduct and/or accumulate an electrical charge (Fig. 9.3). When using these sensors, the soil becomes part of an electromagnetic circuit and the changing local conditions immediately affect the signal recorded by a data logger.
   b. Mobile geophysical tools, however, determine the ability of soil media to conduct an electrical charge in its natural state. In physical terms, this means estimating media resistivity, measured in Ohm-meters (W·m), or its reciprocal, conductivity, measured in Siemens per meter (S m⁻¹). Electrical conductivity of complex soil media comprising solid, liquid and gas components measured in situ is called apparent (or bulk) and it is denoted in the literature as ECa.
   c. Different sensors produce different values (Fig 9.3).

4. Which soil properties can be successfully predicted using vis–NIR spectroscopy?
   a. Laboratory-based visible and NIR (vis-NIR) spectroscopic measurements have been recognized as a promising approach to measure soil properties in dried and ground samples.
   b. On-the-go vis-NIR sensors can be moved across the landscape. However, laboratory-based spectroscopic methods provide better accuracy than static in situ and on-the-go methods.

5. What plant attributes can be detected using LiDAR and ultrasonic measurements?
   a. LiDAR is the acronym for Light Detection and Ranging. A LiDAR system is a distance sensor which includes a laser and an optical sensor. The laser emits a beam of near-
monochromatic, nonscattering (coherent) light with high energy density. If the light is reflected from a target, distance information is extracted by either the triangulation or the time-of-flight (ToF) principle (Hosoiand Omasa, 2009).

b. Laser-based distance measurements for describing crop morphology have been found useful in several studies. Ehlert et al. (2008) and Gebbers et al. (2011) found them suitable for quantifying crop biomass and leaf areas. These sensors have been extensively tested in vineyards and tree crops to estimate shape and leaf area as an input for spraying and other measures (Sanz-Cortiella et al., 2011). Compared to camera-based stereo vision, laser based methods are less sensitive to ambient light conditions. The disadvantage with laser-based techniques is that post processing is needed to build a topology.

c. Bats, dolphins and other animals use acoustic echolocation (ultrasonic signals) for avigation and detection of prey.

d. Llorens et al. (2011) compared ultrasonic and LiDAR sensors for canopy characterization in vineyards. They reported that crop volume and leaf area index were estimated with both sensors with similar precision ($r^2 = 0.5$). Compared to LiDAR, the ultrasonic sensor neglects finer details but data handling is much easier.

6. What sensing principle is frequently used to detect differences in N stress in crops?

a. Most proximal sensors do not measure N stress directly, and therefore N stress is assessed by comparing measured values with a known value. For example, reflectance differences between a fertilized and unfertilized plant. Sensors can be used to quantify the ability of soil to conduct an electrical charge, reflect light, emit radiation, or withstand mechanical distortion. Defining the most effective strategy to process and interpret proximal sensor data is needed to resolve specific agronomic questions, and the failure to establish appropriate procedure may cause data misuse, which could negatively affect local decisions.

b. In many instances, the proper proximal sensing operation requires more than one sensor (employing the principle of sensor fusion) to differentiate two or more physical phenomena. When assessing N stress, an optical sensor may be combined with data collected from an N enriched N strip or soil nutrient measurements using ion-selective electrodes.

7. Why is proximal sensing system calibration important?

a. Calibration is needed to collect accurate information and define the relationship between the measurement and the properties of interest.

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Chapter 10

1. What types of electrical signals would you expect as the output of a sensor?

a. Sensors convert the measured phenomena to a signal that can be read by a computer. The signal might be an analog voltage, an electrical current, a periodic signal with varying frequency, a series of electrical voltage pulses, or even a digital signal that can be decoded by a computer.

2. In open-loop control, why can we not be certain that the speed or rate of an actuator is at its desired value?

a. Open-loop control systems do not measure the resulting output. An example of an open-loop control system would be a DC electric motor that can be supplied with a variable voltage level to control the speed. In such a system, a linear response between the motor speed and supplied voltage is generally expected. However, the motor would turn slower at the same input voltage level as more load is applied to the output shaft. Without measuring the true shaft speed, the open-loop controller is unable to detect the speed difference.

3. In a closed-loop control system, what is the setpoint? How is it related to the error?

a. Closed-loop control systems, also known as feedback control systems, use sensors
to either directly or indirectly monitor the device being controlled. Closed-loop control systems typically measure the resulting actuator status (position, speed, angle, etc.) and use a setpoint for the controlled parameter. The setpoint is the desired rate or position, and can be determined by the operator or by an electric control unit (ECU) based on the current location in a field.

4. Thought experiment: Open-loop control using feedback is never guaranteed to exactly meet the setpoint if only proportional gain is applied to the error. Which gain, integral or derivative, would need to be added to the system to ensure the setpoint is reached?

   a. In addition to a proportional gain, an appropriately-sized integral gain term would help ensure that the setpoint is achieved. For more details, look into the term “step response” in a control systems literature.

5. What are the benefits and drawbacks of a liquid sprayer system with a servo valve to control flow rate?

   a. In liquid chemical application systems, there are many goals, including the need: i) to apply the appropriate amount of active ingredients, ii) to apply an appropriate amount of carrier for adequate coverage, and iii) to apply the appropriate droplet size for good canopy coverage.

   b. The main benefits are that application rate can be varied to achieve variable rate application or to maintain a constant flow rate at varying ground speeds.

   c. The main drawback to a machine with a servo valve, flow meter, and speed sensor is that the pressure in the system varies with the servo valve setting and is not controlled. This leads to variations in droplet size and spray pattern.

6. Why is it possible to control flow rate on a conventional nozzle based liquid application system only by changing the pressure relief valve?

   a. Droplet size is determined by nozzle orifice size and the pressure drop across the nozzle. For a given nozzle orifice, one general equation for flowrate is:

\[
Q = 60C_o A_o \sqrt{2\Delta P/\rho}
\]

where \(Q\) is the Flowrate, \(C_o\) is the Orifice Coefficient, \(A_o\) is the Orifice Area, \(\Delta P\) is the Pressure drop, and \(\rho\) is the Liquid Density. In this equation, if the nozzle and liquid remain constant, the equation simplifies to: \(Q = K (\Delta P)^{1/2}\), where \(K\) is the Nozzle-Density Coefficient. This means that, for any selected nozzle and liquid mixture, the flowrate depends on the pressure drop across the nozzle. Older machines control the flowrate based on the setting of a pressure relief valve that can be either electronic or manually controlled by turning a knob.

7. Why is manure less likely to be applied in a variable-rate manner when compared with granular or liquid-based fertilizers?

   a. Unlike liquid and solid fertilizers, the amount of nitrogen, phosphorus, potassium, and other nutrients contained within manure is highly variable. With such variability, manure is not applied in a variable-rate manner as often as liquids and granular materials. However, it is possible to target application to problem areas in the field.

8. List at least three reasons why it is difficult to apply anhydrous ammonia fertilizer in a variable-rate manner.

   a. Unlike water, anhydrous ammonia in the tank and plumbing lines exists in both liquid and vapor phases. Liquid flow meters are inaccurate due to the presence of the vapor, while gas flow measurement devices don’t work due to the liquid portion. Without the ability to accurately measure the flowrate, it is difficult to accurately control the rates.

   b. For variable-rate anhydrous ammonia application, the product must be cooled sufficiently so that it no longer contains vapor.

   c. Ammonia is not typically pumped, but rather forced out of the tank and through the applicator knives into the soil by the pressure in the tank itself. While ammonia pumps do exist, the caustic and corrosive nature of ammonia means they are not of-
ten used for fertilizer application.

d. Pumps only work will for liquid ammonia and would require that temperatures be held below -28 °F.

9. If you had a PWM controller that incremented its counter 16 million times per second, what would the maximum PWM resolution be if you wanted the frequency to be 20 kHz? What would the BOTTOM and TOP counter values need to be set at?

a. Pulse width modulation functionality is built into most microcontrollers, which are considered the “brains” of an electronic system. In most microcontrollers, PWM functionality is initialized using a counter with three important parameters:

b. BOTTOM, TOP, and COMPARE. The timer counts in increments of one from BOTTOM to TOP. Each time the counter increments, the microcontroller checks to see if the counter value is greater than the COMPARE value. If the counter is less than COMPARE, the PWM signal is set to ON. If it is greater than COMPARE, the signal is set to off.

c. The PWM frequency is the number of times per second that the system counts from BOTTOM to TOP. The PWM resolution is the amount of change of duty cycle that results from a single increment of the COMPARE value.

d. Let’s parse this question. First, we want the frequency of the PWM controller to be 20 kHz. This means we need the timer to increment, or count, from BOTTOM to TOP 20,000 times per second. 1s/20000 is 0.00005 seconds, or 50 μs. Our microcontroller counts at a rate of 16,000,000 increments per second. 1s/16000000 is 0.000000625 seconds, or 0.0625 μs. 50 μs/0.0625 μs = 800 counts per PWM cycle.

e. The maximum PWM resolution is, thus, 1/800, or 0.125%.

f. The BOTTOM would be set to zero, the TOP to 800.

g. The COMPARE setting could be anywhere between zero and 800.

10. How are lightbar guidance and auto-steer guidance similar? What is the major difference? How could the two technologies improve efficiency in a tillage operation?

a. By making perfectly aligned and spaced swaths in the field, GPS Auto Guidance systems minimize fuel consumption and application overlap. In the auto-guidance case, rather than just indicating to the driver that the vehicle is out of position (lightbar), the system physically controls the steering to correct the course. This can be done with a mechanical connection to the steering wheel, or with a hydraulic valve that can adjust the steering angle directly.

b. Auto-guidance systems include the look-ahead distance and one or two PID gain factors from the PID section of the chapter. The look-ahead distance is the point in front of the tractor that is used to calculate how the controller should steer the vehicle.

c. When very small amounts of position error are allowable from one pass to another, such as in strip till and planting operations, it is possible to improve pass-to-pass repeatability by steering both the tractor and the implement. For implement steering, a second RTK GPS receiver is mounted on the implement itself. This receiver monitors the location of the implement and uses either a linkage on the hitch or a steering coulter making contact with the soil to push the implement from side-to-side. Autoguidance steering in combination with implement steering independent of the tractor can reduce misaligned passes to very small levels, potentially to the centimeter range.

d. Both use GPS location and desired travel path to enable the vehicle to stay closer to the desired path. Autoguidance drives the machine, while lightbar guidance informs the driver that the vehicle is off path. Both technologies can be used to reduce both overlap and missed area, which can improve machine and agronomic efficiency.

11. What are two major benefits of ISOBUS using a bus network topology instead of a star topology? (at least two)
a. ISOBUS defines the system for tractors and implements to communicate with one another, as well as standards for machine diagnostics. ISOBUS defines the physical communication layer (i.e., wiring, connectors, signal levels) using the technology developed by Bosch called Controller Area Network, or CAN, version 2.0B. It also standardizes the address numbers for electronic control units (ECU), the priority for different messages, and data formatting for sharing data between the tractor, implement mobile system, and a personal computer (Oksanen et al., 2005).

b. The ISOBUS standard divides the communication network into two separate, but connected, busses. A *bus topology* in computer networking is a shared set of wires that multiple different ECUs can communicate through, whereas a *star topology* is a system where each ECU on the network requires individual connections to the other ECUs.

c. ISOBUS uses a bus rather than star topology. This simplifies the wiring, since all data communication is on the same bus connection.

d. All messages are heard by all controllers, making data logging and machine control easier.

12. How does implement steering improve the potential accuracy of product and seed placement?

a. When very small amounts of position error are allowable from one pass to another, such as in strip till and planting operations, it is possible to improve pass-to-pass repeatability by steering both the tractor and the implement. For implement steering, a second RTK GPS receiver is mounted on the implement itself.

13. How can improved seed placement and seed meter monitoring improve yields?

a. Proper seed spacing is an important factor in maximizing the potential of every seed. Although plant science is not in the scope of this book, yields can be improved through even seed spacing within rows. Monitoring the seed meter speed the seed placement through the system can reduce seed spacing variability, while the operator can be alerted to problems when the monitoring system detects poor performance.

14. What is the Universal Terminal in an ISOBUS system?

a. The Universal Terminal is an ECU with both a screen and user interface that allows the operator to interact with the implement, change settings, create tasks in the field, and collect data from the system (as an applied map, etc.)

b. ISOBUS Universal Terminal allows a single display to be used to control many implements rather than needing a separate control box in the cab for each implement.

15. What are the advantages of filtering messages in an ISOBUS system?

a. To achieve the proper flowrate for each point in a field, a sprayer controller on the implement bus needs to know the ground speed and prescribed application rate. It can ignore messages relating to the tractor’s lighting configuration. This can be accomplished by using a filter on the message identifier to only react to the important messages. Less expensive control electronics can be used for less critical tasks if the controller is able to only act on the messages that it cares about for its specific control function.

**Chapter 11**

1. What type of questions are “best” suited for real-time sensing and application?

a. In real-time sensing and application systems, data is collected and processed as you travel through the field. For example, weeds can be identified and sprayed or nutrient deficiencies are identified and fertilized. An example of a real-time sensing and application system is an optical sensor that uses an algorithm to control fertilizer applicator.

2. What type of questions are “best” suited for mapped-based applications?

a. In the map-based approach, maps are used to identify where and how much of a given treatment is applied. In the map-based approach, maps are used to identify where and how much of a given treatment is applied.
b. A map based approach may use archived information, such as yield maps.

3. Why does water, either too much or too little influence yield or the application of VRA?
   a. In many fields, water, whether too much or too little, limits plant growth (Clay and Trooien, 2017). Differential amounts of water and associated stress can impact many factors including the N mineralization rate, weed distribution, and the ability of the plant to resist pests (Kim et al., 2008; Hansen et al., 2013). For example, if water stress reduces the ability of the plant to respond to diseases in summit and/or shoulder areas, as suggested by Hansen et al. (2013), or reduces the N fertilizer efficiency as suggested by Kim et al. (2008), then these areas could be targeted for corrective treatments. Theoretically, the targeting of treatments to critical areas should improve the efficiency of the applied treatments, help close the gap between the observed yield and the plants genetic potential, reduce pest resistance to cultural and chemical control techniques, and reduce water and carbon footprints while enhancing economic returns.
   b. The bottom line is that water impacts many plant properties that can be managed using VRT.

4. How does flow-based and pressure-based control systems differ?
   a. A “flow-based” control system regulates the flow to vary the rate (Fig. 11.4). Flow-based systems are commonly used because it is easier to manage than pressure-based systems.

5. Explain how variable cultivar seeding is accomplished?
   a. In the multicultivar planter, two or more cultivars can be planted in a single field at variable seeding rates. The cultivars are stored in separate holding boxes, from which they are metered by multiple electric motor metering units to a single seed tube or belt or brush conveyor (Fig. 11.8). During planting, the RCM receives feedback on ground speed, desired cultivar for the location, and target plant population. The RCM uses this information to control the cultivar and seeding rate. When switching from one hybrid or cultivar to another, the planter electronic control unit (ECU) synchronizes the turning of one meter OFF and turning the other on.

Chapter 12

1. List at least three types of field level data that are commonly collected and georeferenced.
   a. Soil survey (SSURGO), crop yield, elevation, terrain features, topography, soil electrical conductivity (EC), organic matter, soil moisture, soil nitrate, pH, P, K, S, Mg, and other micronutrients, Imagery collected by satellites, airplanes or unmanned aerial vehicles, as-applied and as-planted maps, Machine information that includes fuel use, engine load, and rpm, and field scouting for pests and diseases.

2. Data can be either __________ or __________ records.
   a. Qualitative or quantitative.

3. List at least four ways precision agriculture tools are used that can be beneficial to a farmer or trusted consultant.
   a. Nutrient management planning and field execution, crop scouting for diseases and pests, field documentation, and/or verification, record keeping, end-of-season analyses, benchmarking, sustainability and environmental verification.

4. In what time-period were computers and geographic information systems first used to identify the location of sampling points (otherwise known as precision agriculture)?
   a. See Figure 12.2

5. Thanks to what two factors did “Decision Agriculture” or “Digital Agriculture” become a reality?
   a. Computers with GIS and GPS

6. What type of field boundary do precision agriculture data services most often use and what does it represent.
a. A key information layer used by most precision agriculture data services is the field boundary. In many situations, spatial data is linked back to the field boundary. However, different types of field boundaries may exist. For example, most farmers and agronomists use what is called the operational boundary, which represents the tilled or managed area of a field. The operational boundary is commonly collected using an ATV equipped with differential GPS (DGPS) or drawn using a mapping program. Operational boundaries are commonly used to determine exact acres for management decisions and are produced by clipping soil and imagery data layers. Other boundaries may be associated with the legal land descriptions (legal parcels), the USDA Common Land Units (CLU), crop zones, and management zones.

7. What are the four main data classification types? List an example of each.

a. Agronomic data represents information that was compiled from individual field operations or about soil and crop conditions at the field or subfield level.

b. Machine data represents information collected from agricultural machinery such as tractors, harvesters, sprayers, fertilizer applicators and implements.

c. Production data includes all other data including farm data, notes, weather data, application dates, and planting dates.

d. Remote sensing data can be collected with small unmanned aerial systems (SUAS). Data collected for these systems can be used for many different applications including directing scouting, determining plant emergence rates, and identifying pest control skips.

d. Identify poorly drained areas that may require tile drainage,

e. Discover man-made variability caused by equipment and other field operations (Fig. 10.8 and 10.9),

f. Improve scouting,

g. Smart Scouting, remote sensed imagery allows for growers to “see” what is happening in the field beyond the naked eye,

h. Aids in the collection of data seen and helps to properly evaluate treatment effects,

i. Identify fertilizer and pesticide requirements,

j. Manage nitrogen in corn (imagery can show where too little or too much nitrogen has been placed and help diagnose application issues),

k. Make fungicide decisions in corn where some areas of the field are showing significant heat sources that may indicate a disease infestation,

l. Assess the success of field and remediation treatments.

9. What would be the main purpose of utilizing multiyear analyses?

a. Multi-year analysis provides perspective over time. This process combines the data, such as yield maps from multiple years into a single layer to delineate management zones.

10. In precision agriculture, _________ is used to identify trends, evaluate spatial relationships, and predict values at locations where information was not collected.

a. Statistics

11. How has data mining made its way into the agricultural sector?

a. Data mining is the process by which information is extracted from data and output in an understandable format for analysis purposes. Analytical processes find patterns within large datasets that can be used to extract information and develop summaries.

b. Data mining technology has made its way into the agricultural sector in the form of
predictive modeling or more specifically machine learning.

12. What is data interoperability and why is it important to precision agriculture?

a. Interoperability is the ability of a system or a product to work with other systems or products without special effort on the part of the user. A component of interoperability is accurate communication of equipment manufactured from different companies.

13. List and define each of the components of Digital Agriculture.

a. Digital agriculture is evolving today as the industry develops services and technologies to permit the wireless transmissions of data along with analytics to derive information. Digital Agriculture combines multiple data sources with advanced crop and environmental analyses to provide support for on-farm decision making. Digital Agriculture is made up of many components (Fig. 10.7). These components are used to make decisions based on social, economic, and environmental goals within a farming operation. When a producer utilizes Digital Agriculture, they are advancing their operation by combining the latest technology with best management practices to increase the value of many aspects on the farm. The components within Digital Agriculture include **Precision Agriculture, Prescriptive Agriculture, Enterprise Agriculture**, and **Big Data**.

14. What is the Internet of Things (IoT)?

a. The network of physical objects or “things” embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data. The Internet of Things (IoT) allows objects to be sensed and controlled remotely across existing network infrastructure. This creates opportunities for more direct integration between the physical world and computer-based systems and results in improved efficiency, accuracy, and economic benefit. Each thing is uniquely identifiable through its embedded computing system, but is able to interoperate within the existing internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020.

15. What are two pros and two cons of data sharing?

a. In May of 2015, the American Farm Bureau released the *Privacy and Security Principles for Farm Data*. This document outlined preferences and common terminology that should be considered by data service providers. Those that have signed this document represent the agriculture industry and farmer organizations committed to ongoing engagement and dialogue. Producers should work with their (or their prospective) Agricultural Technical Provider(s) to obtain the company data privacy policy. Many companies have agreed to the Privacy and Security Principles for Farm Data Policy that was proposed by the American Farm Bureau. This program is called the American Farm Bureau Privacy Policy (AFBF Privacy Policy). We believe that prior to selecting a data management provider, investigate if the company is aligned with the AFBF Privacy Policy. Data sharing can add value to the information.

b. While data sharing seems simple, it brings complexity due to the legal aspects associated with data use or access. It is proven, that the sharing and collaborative aspect of data is beneficial and ultimately valuable but the problematic nature of data sharing limits its value. While data sharing can minimize duplicative efforts, it also leads to complex situations and unintentional interpretations of information. Potential benefits of sharing data include:

- Minimizing duplicate data collected or created,
- Utilizing data that has been collected more quickly
- Creating new insights and verification of original analysis from re-analysis of data
- The ability of scientists and researchers to create high quality analyses that have not been explored, leading to new discoveries.
- The ability of large datasets to generate trustworthy answers and solutions to im-
important and complex questions within agriculture such as water quality issues within large watersheds, and

- Ability to provide data for benchmarking capabilities.

Potential downfalls of sharing data includes:

- Misinterpretation of data due to complexity
- Misinterpretation of data due to the poor quality
- Use of data in ways other than intended.

Chapter 13

1. List two benefits of on-farm replicated strip trials as a research tool in agronomic studies, specifically for farmers, agronomists, and researchers.

   a. On-farm research includes any experiments that farmers conduct to test new products, technologies and management practices prior to wide-scale adoption on their farm. In many fields, these treatments are applied in strips across the entire field. As with all experiments, they are most successful when they are replicated and based on carefully constructed questions or hypotheses.

   b. Created locally based information using your production system

   c. Test products that are being marketed to you.

   d. Allows you to assess common practices.

2. List key differences between on-farm trials conducted by farmers and small-plot controlled field experiments done by university researchers and graduate students.

   a. Use of field scale equipment using technologies that are used on your farm. On-farm research networks offer new ways to bring together science technology, and a farmers’ own personal knowledge, ideas, and experiences. These networks help to enhance the understanding of how and where farm management improvements are possible.

   b. Small plot and field-length strips are fundamentally different. In small plots, variability in soil properties within the plots is minimized, where in field length strips, it is not.

3. What aspects of on-farm experiments require the most attention?

   a. Ask the right question.

4. On-farm strip trials fall into the category of “learning by doing”. List the role of modern technologies, the internet and social media in on-farm research.

   a. Table 13.2

5. What new technologies may be helpful to conduct on-farm research in the near future? Why?

   a. See Table 13.4

6. Why is a research hypothesis needed and what are the key elements of a research hypothesis?

   a. A research hypothesis is a simple statement that captures what researchers and farmers plan to discover from their research.

7. Develop a short protocol for the following on-farm trials testing (i) effect of animal manure on wheat yield in rainfed conditions, and (ii) effect of in-furrow insecticide applications on corn yield in irrigated conditions.

   a. Please use your imagination to answer this question.

8. List key climate and environmental variables needed to interpret results from on-farm trials studying (i) foliar fungicide applications on soybean and (ii) variable-rate planting on corn.

   a. Once the research question has been identified and the treatments selected, the most appropriate response variables must be chosen. The response variable is the available soil, crop or other variables that respond to the treatments. A response variable should be measured or collected if it is important for interpreting the results of the on-farm trial or if it improves the sensitivity of the analysis. Common response variables to measure for on-farm research are yield (bushel per acre), soil erosion (ton per acre per year), soil nutrient levels (ppm), disease level (e.g., % leaf coverage), rainfall, temperatures.

   b. See Table 13.2 and 13.3.

9. Describe the role of aerial imagery in cleaning yield data from on-farm trials.
a. When conducting on-farm research, three goals are to collect accurate information, archive the data for future use, and to convert the information into better decisions. Aerial imagery can be used to identify anomalies such as where water is ponding, hybrid or variety changes, applications that do not match the protocol, and nitrogen skips, as well as identify management or equipment issues that may have affected some treatment areas but not others.

10. What can go wrong right from onset of planning a good on-farm trial?

   a. The project can go wrong if the question is not clearly identified. The keys for success of on-farm trials are: i) form a research hypothesis and make sure it is simple and practical by comparing only a limited number of treatments within a field; ii) follow the rules of designed experiments by replicating treatments, using randomization or personal knowledge of within-field variability or within-field management history; iii) keep all other management practices the same, except those used in treatments; and iv) develop a protocol that clearly outlines each step to improve the chances of having a successful experiment.

11. What are common considerations when using farmers’ equipment such as planters or sprayers to conduct on-farm research?

   a. The experiment must match the equipment.

12. Describe how publicly available tools can be used to select on-farm research locations.

   a. See Table 13.2.

   b. There are many web-sites that highlight and provide guidance for on-farm studies. See https://onfarmresearch.sdsoybean.org/.

13. Explain three factors to consider when selecting a research site.

   a. Field selection for on-farm trials depends on the product or practice being tested. Some trials are targeted to specific geographical locations or field areas that have certain characteristics. For example, some experiments require areas of low soil pH and/or low soil organic matter (Fig. 13.5 A.),

14. Explain the difference between “signal” and “noise” when analyzing data.

   a. The signal is what we try to identify based on the research hypothesis and the noise is mostly random variation or other unidentified error sources.

15. Give examples of metadata for on-farm research. What is the role of metadata?

   a. Metadata is information that describes how the data or experiments were conducted, details about calibration, extent and severity of the problem, details about what and when the treatments were applied, and who conducted the soil and plant analyses. Metadata helps to interpret the data. For example, foliar disease levels, climatic conditions, plant growth stage, seeding and germination rates, estimated yields, and leaf area can help explain yield differences between fungicide treatments.

16. List advantages of joining an on-farm research network.

   a. While data collected in individual on-farm replicated trials can be valuable, organizing or joining an on-farm research network has many advantages. The most prominent advantage is increasing the ability to better summarize data. As part of a research network, data collected from individual trials will be combined with other similar trials and data results made available. This may expand the types of questions that can be asked. If data are stored properly, they may be used later for even more complicated analyses.

Chapter 14

1. Nitrogen and P are essential in increasing yield in agricultural crops. However, when applied in excess, undesirable impacts on the environment can occur. What are the environmental impacts of excess N and P in the environment?

   a. Agricultural pollution comes from inputs that are not utilized by the target crop. Fertilizer N can be lost due to gaseous plant emissions, soil nitrification and denitrification, volatilization, surface runoff, and leaching. In addition, N fertilizer can be immobilized
into microbial biomass and build soil organic matter. Phosphorus, being strongly sorbed to the soil matrix, is generally lost through soil erosion and surface runoff, although P leaching can also occur where soil P sorption is low as in sandy soils and with repeated P fertilizer application.

b. Nitrogen in nitrate (NO₃–N) form can cause health problems when it accumulates in groundwater used for drinking. Nitrate–N is not held tightly by soil particles, and thus vulnerable to movement with percolating water. Nitrate–N that moves below the root zones can enter the groundwater, potentially causing health issues if consumed. Losses of N through soil erosion and runoff also contribute to lower groundwater quality.

2. Application of fertilizers at the right amount, right place and timing is a better way to judiciously use them. How can a farmer best use site-specific nutrient management in his cropping production system to lessen N and P losses?

a. Precision, or site-specific nutrient management (SSNM), involves better utilization of fertilizer inputs by following the 4Rs—applying the right nutrient source, at the right rate, at the right time, and in the right place (International Plant Nutrition Institute, 2012). For efficient and effective SSNM, use of soil and plant nutrient status sensing devices, remote sensing, geographic information systems, decision support systems, simulation models, and machines for variable application. While, traditional practice of farmers is to apply the same fertilizer management over whole fields (Chapter 2; Kitchen and Clay, 2018). Matching supply with spatial plant demands can improve fertilizer efficiency.

3. Weeds typically occur in patches rather than uniformly across a fields. Site-specific weed management uses satellite and aerial images to distinguish weeds and crops for selective treatment thereby reducing amount of herbicide use. What are the direct and indirect impacts of reduced herbicide footprint in the environment?

4. Soil applied herbicides remain an important part of weed control programs in agricultural crops. Regardless of when and how an herbicide is applied to soil, the effectiveness of soil-applied herbicides is influenced by the physical and chemical properties of the soil. How can knowledge on soil properties best be used in site-specific weed management to benefit the environment?

a. Another environmental benefit of site-specific weed control could be realized when information on soil variability is used for decision making. Herbicide leaching, rate of adsorption, and efficacy are influenced by clay and organic matter content (Al Gaadi and Ayers, 1999; Boesten, 2000; Đurović et al., 2009; Tielen, 2010). The amount of herbicide lost to leaching is affected by soil texture, herbicide adsorption to soil colloids, and water movement through the soil. Herbicides such as the salt forms of 2,4-D have low tendency to be adsorbed by soil colloids and leach with percolating water.

5. Uniform insecticide application simplification. How does this affect the pest and/or natural enemy’s dynamics in the field? How will this impact insect community structure and biodiversity?
a. Site-specific insecticide application has demonstrated success in reducing total insecticide applications in numerous fields. Studies by Dupont et al. (2000), Fridgen et al. (2003) and Sudbrink et al. (2002) showed that site-specific application can reduce total insecticide use by 20 to 44% compared to uniform applications without a yield loss.

b. Reductions in amount of pesticide applied lessens the deleterious effect on groundwater and surface water, and benefit natural enemies of many pests. Midgarden et al. (1997) observed greater densities of predatory and parasitic insects in site-specific treated fields compared with uniform field-wide application.

6. Variable-rate irrigation reduces the total volume of irrigation water used to grow crops. What information and/or data is used in variable-rate irrigation technology?

a. The soil water content, the soil water holding capacity, expected plant demand, soil water holding capacity, available irrigation water, salinity, drainage.

**Chapter 15**

1. How can the use of UAVs in agriculture manage economic risks?

a. UAVs can manage production risks. UAVs have the ability to determine crop stress from diseases/pests early. However, flying UAVs without a license or recklessly will increase legal risks.

2. A producer is interested in investing in an advanced sprayer technology. The new technology has an initial investment of $60,000, an economic life of seven years, and an interest rate of 8%. Furthermore, additional operating costs for the new sprayer technology include an annual subscription fee of $1000 per year and an anticipated increase in repairs and maintenance (R&M) of $2000 per year. If the producer adopts the technology, he anticipates a $6,000 per year savings in chemicals spent compared to the current spraying operation. What is the Net Present Value of this investment and why?

<table>
<thead>
<tr>
<th>Year</th>
<th>Sprayer savings</th>
<th>Total benefits</th>
<th>Additional costs</th>
<th>Net cash flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6000</td>
<td>6000</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>2</td>
<td>6000</td>
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<tr>
<td>7</td>
<td>6000</td>
<td>6000</td>
<td>3000</td>
<td>3000</td>
</tr>
</tbody>
</table>

A negative NPV indicates that the investment should be rejected. Internal rate of return (IRR)

Calculated in Excel using the command, =IRR(numbers, guess)

For these calculations, the first number in the cash flow represents the investment and should be negative the rest of the numbers are the net cash flow values from above. We used the command =IRR(C6:j6,0.1).

<table>
<thead>
<tr>
<th>Investment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net cash flow</td>
<td>-60000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>IRR</td>
<td>-21%</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The negative value of -21% indicates that the investment should not be made.

1. How would a nefarious marketing scheme misuse economic analysis to make their product relatively more attractive than the alternative product?

a. When conducting economic analyses, it is important to include factors such as human capital costs and to discount the flow of expense and revenue over time. Wide variations in outcomes are possible by omitting important costs or by improperly calculating returns on investment. The reader should be cognizant of how marketing efforts employ economic analysis to determine if those calculations were performed correctly.

2. In less than 300 words, explain to a nonagriculturalist why lack of cellular phone connectivity adversely impacts production agriculture.

a. See the section on Barrier to full utilization of precision ag: Broadband Connectivity.

3. Why do information intensive technologies
such as yield monitor and soil sampling have relatively lower adoption levels than automated technologies?

a. Some technologies reduce the management skill required to do tasks such as automated guidance; subsequently, these have relatively higher adoption rates than technologies that do not share in improving utility. Other technologies require additional management ability but provide opportunity for increased production and profitability when used properly such as yield monitor data. However, data intensive technologies have been adopted and utilized less than their automated technology counterpart.