Sensors and Satellites
Careers and Technology in Agriculture

Grades: 6–12

Purpose
Students will:
- Discuss modern applications of electronics and sensors in wheat production and harvest.
- Conduct an experiment to find infrared light.
- Interpret satellite images as applied to farming.
- Explore career opportunities in agricultural electronics and technology.

Keywords
wheat, careers, precision agriculture, electronics, satellites, sensors, infrared light, Global Positioning Systems (GPS), Geographic Information Systems (GIS), computers

Materials
ACTIVITY ONE
- "Discovering Infrared Light" worksheet
- One glass prism (plastic prisms do not work well for this experiment)
- Three alcohol thermometers
- Black paint
- Scissors or a prism stand
- Cardboard box (photocopier paper box works well)
- 1 blank sheet of white paper
- 1 halogen lamp, 100 watt bulb

ACTIVITY TWO
- Soil Moisture Map

ACTIVITY THREE
- "Reading Satellite Images" worksheet

ACTIVITY FOUR
- "Careers in Ag Technology" worksheet

Interest Approach or Motivator
Ask students how much time they spend using computers—on their smart phones, playing video games, etc. Ask what jobs they think might be available that would make use of their computer skills. Ask how much they think computers are used in producing and harvesting wheat. Read and discuss background and vocabulary.

Background
American agriculture owes much of its success to the **innovative** thinking of farmers looking for ways to solve problems and make farming easier. Thomas Jefferson was an avid farmer and

Replica of Jefferson's moldboard plow

inventor who saw a problem with the crude wooden plows used by farmers in his day. They barely scratched the surface and merely loosened the topsoil, making it **susceptible** to washing away at the first hard rain. Jefferson's solution was the moldboard plow, which lifted and turned the **sod**. With this tool he could plow to a depth of about six inches. This enabled farmers to **contour-ridge erodible** fields, plow out shallow ditches, and **ridge** poorly-drained flat lands.

The Industrial Revolution brought more complicated machines. Instead of harvesting wheat by hand with a sharp blade, wheeled machines cut a continuous **swath**. Instead of threshing wheat by beating it with sticks, threshing machines separated the seeds from the heads and stalks. The first tractors appeared in the late 19th century and displaced horses as a power source.
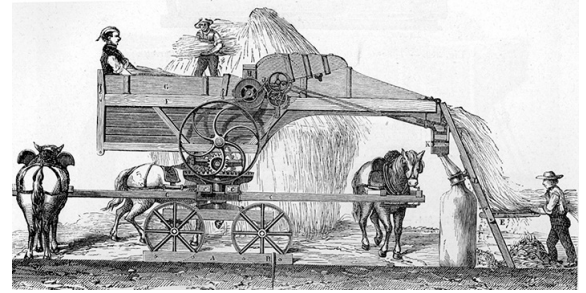
Threshing Machine

Wheat producers today makes use of airplanes and helicopters, and even **unmanned aerial vehicles** (UAVs, or drones) for planting and spraying **fumigants** to control insect pests and diseases. The internet transmits vital weather data and other important information. **Global Positioning Systems** (GPS) and **Geographic Information Systems** (GIS) are widely used to make the most precise use of resources and to protect the environment.

Precision farming uses **data** at the level of the square meter or decimeter or even of a single plant. It uses the data to determine precisely how much seed, fertilizer and crop protection to use within a field or among fields. It turns plows, planters, spreaders, sprayers and other add-ons into intelligent equipment with **sensors**, software and wireless connectivity.

Some of the most modern tractors can even drive themselves, steering with the help of satellite technology (GPS). Computers on board the tractors download data about crops and soil that go straight to farm managers. They link with ground sensors and UAVs, using **infrared thermal** cameras and can detect to within a square meter where the most **fertile** or waterlogged places are in a field.

Sensors are critical to some of the most important developments in agriculture in recent years. A sensor detects events or changes in its environment and responds with a corresponding output. Sensors may provide various types of output, but typically use electrical signals or signals that are sensitive to light. For example, a **thermocouple** in a heating system generates a known voltage (the output) in response to its temperature (the environment). A mercury-in-glass thermometer converts measured temperature into expansion and contraction of a liquid, which can be read on a **calibrated** glass tube.

Some of the most important sensor technology in agriculture relies on infrared light to provide the trigger for desired outputs. Infrared mapping helps farmers diagnose their fields and predict crop yields. Areas where the crops are growing poorly may be a result of poor soil nutrition, or irrigation problems, and the infrared data can help farmers spot problems early.

An important sensor system in agriculture uses infrared and **near infrared (NIR)** light to determine the nitrogen level in a crop. Nitrogen levels are determined based on the crop's **normalized difference vegetative index (NDVI)**. The NDVI is an index of plant "greenness" or **photosynthetic** activity. Vegetation that is photosynthetically active absorbs most of the red light that hits it while reflecting much of the near infrared light. Vegetation that is dead or stressed reflects more red light and less near infrared light. By taking the ratio of red and near infrared bands from a remotely-sensed image, an index of vegetation "greenness" can be defined. Using satellite imagery, the system determines the NDVI of a test strip that is rich in **nitrogen** and compares it with the rest of the crop to calculate nitrogen requirements for the growing season. Better nitrogen management not only helps producers get more value for their nitrogen investment but also reduces the risk of environmental pollution.

Dead Leaf   Stressed Leaf   Healthy Leaf
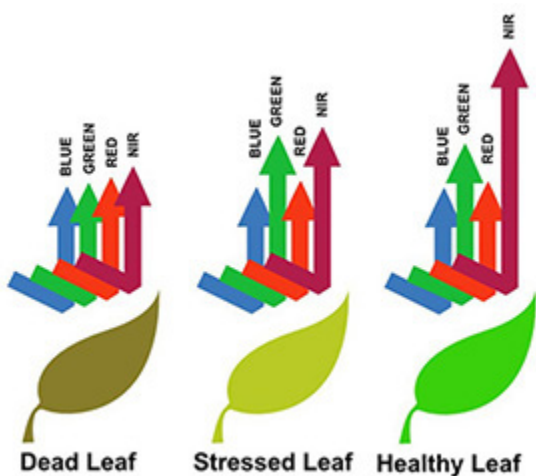
New technology helps wheat harvesters and producers with another problem—the shortage of labor. With new technology workers are still needed, but the jobs often require specialized skills for operating and maintaining complicated equipment. Farm equipment dealers and manufacturers, grain milling operations, research firms, as well as some state and government agencies are all employers looking for employees with knowledge of and skills in the fields of electronics and computer sciences. A sampling of some of the electronics skills required include the following:

- Installation, maintenance and repair of electrical systems
- Reading blueprints and diagrams while troubleshooting and diagnosing electrical problems
- Performing preventative maintenance to avoid operational failures of electrical systems
- Installing electrical wiring, assembling electrical parts and testing fixtures and components that provide electricity to related instruments
- Tearing apart and reassembling equipment
- Reading dials and meters to determine amperage, voltage, electrical output and input at specific operating temperature to analyze parts performance
- Remote sensing data collection and management
- Big data mining, including pattern detection, graph analysis, or statistical analyses from a variety of disparate sources.

Procedures

ACTIVITY ONE

1. As an introduction to this activity, show the NASA video, "Exploring Energy:Infrared," https://www.youtube.com/watch?v=zmiU5tJRJd4
2. Provide copies of the "Discovering Infrared Light" worksheets included with this lesson.
3. Students will conduct the experiment described to recreate the discovery of infrared light.
4. Students will record the results of their experiment using the worksheet provided.

ACTIVITY TWO

1. Provide color copies or project onto a whiteboard the information on the Soil Moisture Map provided with this lesson. The map can also be found online at the NASA Earth Observatory website: http://earthobservatory.nasa.gov/IOTD/view.php?id=87036
2. Discuss the information provided with the map.
3. Students will answer the following questions, based on the map and map legend:
   - Which region of the US has the most soil moisture?
   - Which region has the least?
   - Wheat harvesters cannot operate their heavy machinery in fields that are wet because the machinery gets mired in the mud. In which region would harvest be most difficult during the time period pictured?
   - Dry conditions are best for wheat harvest. In which region are conditions best for wheat harvest during the time period pictured?
   - Dry soil during wheat planting may result in poor stand establishment and may cause plant stress when dryness occurs during the periods of flowering and seed set. For this reason, which region(s) is most likely to require irrigation, if planting and early development occur during the time period pictured.
4. Find the part of the state where you live. What does the map tell you about soil moisture where you live?
   - Which part of your state has the highest amount of soil moisture?
   - Which has the least?
   - Where in the state would you most likely need to irrigate?
   - Where in the state are conditions best for harvesting wheat?
   - Where in the state are the conditions least favorable for harvesting wheat?

ACTIVITY THREE
1. Divide the class into groups of three or four, and tell each group they will be analyzing three satellite images of the same piece of land. The information in the images provides information about the land that would be useful to a farmer. One image shows vegetation density on the land, one shows where there is water deficit and one shows places where crops are under stress.
2. For each group, provide color copies of the satellite images included with this lesson or project the image for groups to inspect one at a time.
3. Students will answer the questions included with the satellite images.
4. Each group will develop a plan for best use of the land, based on what they see in the satellite images
5. Each group will present its plan to the class.
6. The class will vote on the best plan.
7. Lead a class discussion about the usefulness of satellite images in wheat production and harvest.

ACTIVITY FOUR
1. Provide copies of the "Careers in Ag Technology" worksheet.
2. Students will each use one or more of the career website addresses provided to identify five jobs in the field of agricultural electronics and technology.
3. Students will use the worksheets to record information about the jobs they find.

Enriching Activities
ACTIVITY ONE
   Invite a farmer to class to discuss and demonstrate how smart phones, etc., are used in agriculture.

Vocabulary
calibrated— having measuring marks (as a thermometer tube)

contour ridge— small earthen ridges, with an upslope furrow which accommodates runoff from a catchment strip between the ridges

data— facts about something that can be used in calculating, reasoning, or planning

erodible— susceptible to wearing away by or as if by the action of water, wind, or glacial ice

fertile— producing vegetation or crops plentifully

fumigant— a substance used in the application of smoke, vapor, or gas especially for the purpose of disinfecting or of destroying pests

Geographic Information System (GIS)— a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

Global Positioning System (GPS)— a multi-use, space-based radionavigation system

infrared— being, relating to, producing, or using rays like light but lying outside the visible spectrum at its red end

innovate— to introduce something new

near infrared (NIV)— the region closest in wavelength to the radiation detectable by the human eye

nitrogen— a colorless, tasteless, odorless element that occurs as a gas which makes up 78 percent of the atmosphere and that forms a part of all living tissues

normalized difference vegetative index (NDVI)— an index of plant "greenness" or photosynthetic activity

nutrient— something that furnishes nourishment

photosynthetic— having to do with the process by which plants that contain chlorophyll make carbohydrates from water and from carbon dioxide in the air in the presence of light

precision farming— a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops

ridge— a raised or elevated part or area

sensor — a device that detects a physical quantity (as a movement or a beam of light) and responds by transmitting a signal

sod — the grass-covered and herb-covered surface of the ground

susceptible — having little resistance

swath — a row of cut grain or grass

thermal — of, relating to, caused by, or saving heat

thermocouple — a device for measuring temperature in which a pair of wires of different metals (as copper and iron) are joined and the free ends of the wires are connected to an instrument (as a voltmeter) that measures the difference in potential created at the junction of the two metals

thresh — to separate seed from a harvested plant especially by using a machine or tool

topsoil — surface soil usually including the rich upper layer in which plants have most of their roots and which the farmer turns over in plowing

unmanned aerial vehicle (UAV) — an aircraft with no pilot on board. UAVs can be remote controlled aircraft (e.g. flown by a pilot at a ground control station) or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems.

yield — the amount or quantity produced

Standards

National Ag Literacy

1. Agriculture and the Environment
    Describe resource and conservation management practices used in agricultural systems

2. Plants and Animals for Food and Fiber
    Identify farm practices for plant protection

4. Science, Technology, Engineering and Mathematics
- Identify specific technologies that have reduced labor in agriculture
- Discuss how technology has changed over time to help farmers/ranchers provide more food to more people
- Provide examples of science and technology used in agricultural systems (e.g., GPS, artificial insemination, biotechnology, soil testing, ethanol production, etc.); explain how they meet our basic needs; and detail their social, economic, and environmental impacts
- Identify science careers related to both producers and consumers of agricultural products
- Identify current and emerging scientific discoveries and technologies and their possible use in agriculture (e.g., biotechnology, bio-chemical, mechanical, etc.)
- Evaluate the benefits and concerns related to the application of technology to agricultural systems
- Predict the types of careers and skills agricultural scientists will need in the future to support agricultural production and meet the needs of a growing population

Content Standards

Geography–2,3
Physical Science—2B, 3A, 4ABC
Life Science—1C, 2A, 3D
Engineering Design—1AB, 3AC

Resources

- Agriculture and Forestry Careers: http://www.environmentalscience.org/careers/agriculture-and-forestry
- Careers in Agriculture (Georgia Agricultural Education): http://www.gaaged.org/page.aspx?ID=353
- Cool Cosmos, Your Infrared Guide to the World and the Universe Beyond, Infrared Processing and Analysis Center (IPAC), NASA, http://coolcosmos.ipac.caltech.edu

- "Exporing Energy: Infrared," NASA Goddard, https://www.youtube.com/watch?v=zmiU5tJRJd4
- Food, Agriculture and Natural Resources Careers, USDA Living Science, https://www.agriculture.purdue.edu/usda/careers/contactus.html
- MyCAERT, http://www.mycaert.com/career-profiles/
- Occupational Outlook Handbook, Bureau of Labor Statistics, US Department of Labor, http://www.bls.gov/ooh/
- Study.com, http://study.com/article_directory/q_p/page/Agriculture/q_p/Careers_and_Occupations_List.html

Sources/Credits

"Electronics/Electrician," AgCareers.com, http://www.agcareers.com/career-profiles/electrician-electronics-technician.cfm

Herring, David, "Precision Farming," Earth Observatory, NASA, http://earthobservatory.nasa.gov/Features/PrecisionFarming/

"The Herschel Experiment," Cool Cosmos, Infrared Processing and Analysis Center, Science and Data Center for Infrared Astronomy, NASA: http://coolcosmos.ipac.caltech.edu/page/lesson_herschel_experiment

Thompson, Pat, "Making Sense of Sensors, Sensors and Satellites in Ag Technology," Oklahoma Ag in the Classroom.

Discovering Infrared Light

Infrared is a form of light that we cannot see with our eyes but that we can sometimes feel on our skin as heat. Visible light, the only light our eyes can see, makes up just a tiny sliver of all the light in the world around us.

Infrared light falls just outside the visible spectrum, beyond the edge of what we can see. Sir William Herschel discovered the existence of infrared light by passing sunlight through a glass prism in an experiment similar to this one. As sunlight passed through the prism, it was dispersed into a rainbow of colors called a spectrum. A spectrum contains all of the visible colors that make up sunlight. Herschel was interested in measuring the amount of heat in each color and used thermometers with blackened bulbs to measure the various color temperatures. He noticed that the temperature increased from the blue to the red part of the visible spectrum. He then placed a thermometer just beyond the red part of the spectrum in a region where there was no visible light and found that the temperature was even higher. Herschel realized there must be another type of light beyond the red, which we cannot see. This type of light became known as infrared. Infra is derived from the Latin word for "below."

Materials

- One glass prism (Plastic prisms do not work well for this experiment.)
- Three good alcohol thermometers
- Black paint
- Scissors or a prism stand
- Cardboard box (photocopier paper box works well)
- 1 blank sheet of white paper
- 1 halogen lamp, 100-watt bulb

1. The experiment may be conducted outdoors, around noon on a sunny day. However, results will be more consistent if conducted indoors with artificial light (halogen lamp).
2. Blacken the thermometer bulbs with black paint or marker, covering each bulb with about the same amount of paint. (The bulbs of the thermometers are blackened in order to better absorb heat.)
3. After the paint has completely dried on the thermometer bulbs, tape the thermometers together such that the temperature scales line up, as in Figure 1.
4. Place the white sheet of paper flat in the bottom of the cardboard box.
5. Carefully attach the glass prism near the top edge of the box facing the sun. If you do not have a prism stand (available from science supply stores), the easiest way to mount the prism is to cut out an area from the top edge of the box. The cutout notch should hold the prism snugly, while permitting its rotation about the prism's long axis (as shown in Figure 2). That is, the vertical side cuts should be spaced slightly closer than the length of the prism, and the bottom cut should be located slightly deeper than the width of the prism.
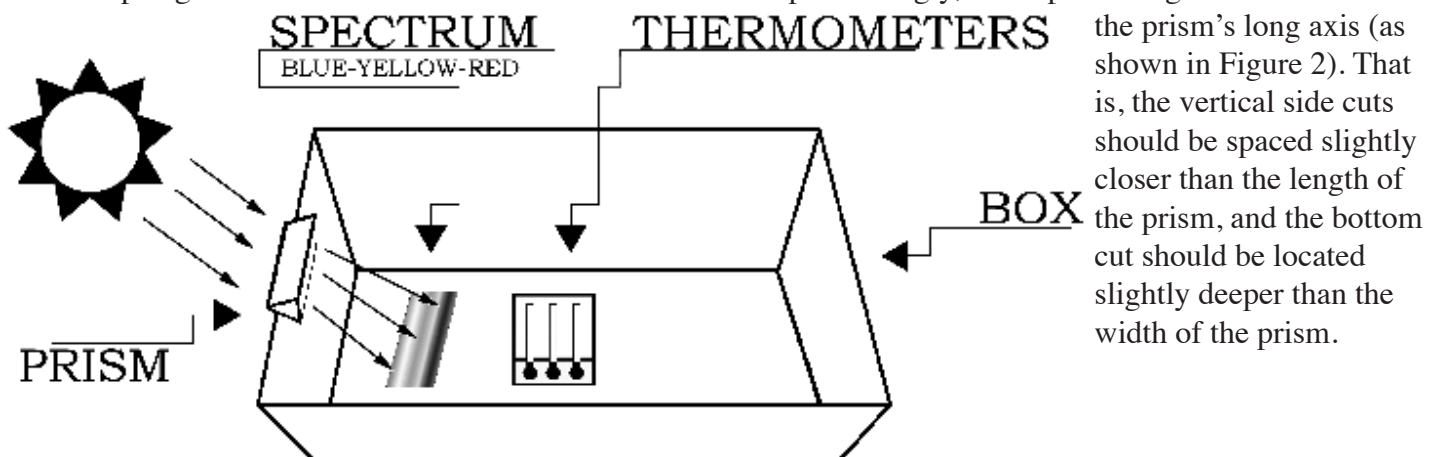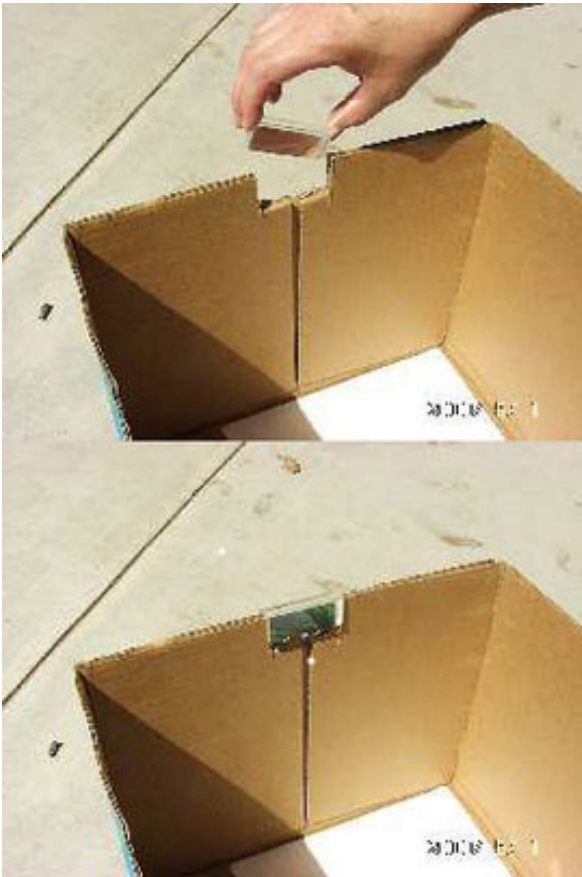

Figure 1

Figure 2

6. Slide the prism into the notch cut from the box. Place the halogen lamp so it shines on the prism. Rotate the prism until the widest possible spectrum appears on a shaded portion of the white sheet of paper at the bottom of the box. The light-facing side of the box may have to be elevated to produce a sufficiently wide spectrum.

7. After the prism is secured in the notch, place the thermometers in the shade if you are working outdoors or simply away from your artificial light source if you are working indoors. Record the ambient air temperature. Then place the thermometers in the spectrum such that one of the bulbs is in the blue region, another is in the yellow region, and the third is just beyond the (visible) red region (as in Figure 3). Note: Depending on the position of the prism relative to the light, the colors of the spectrum may be reversed from what is shown in the figures.

8. It will take about five minutes for the temperatures to reach their final values. Record the temperatures in each of the three regions of the spectrum: blue, yellow, and just beyond the red. Do not remove the thermometers from the spectrum or block the spectrum while reading the temperatures.
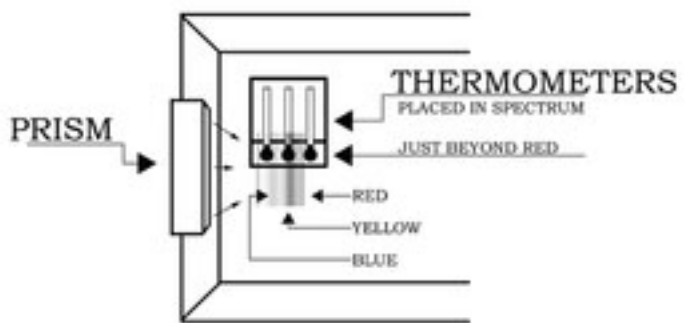
The temperatures of the colors should increase from the blue to red part of the spectrum. The highest temperature should be just beyond the red portion of the visible light spectrum. This is the infrared region of the spectrum.

Figure 3

Herschel's experiment was important not only because it led to the discovery of infrared light, but also because it was the first time that it was shown that there were forms of light that we cannot see with our eyes.

Source: "The Herschel Experiment," Cool Cosmos, Infrared Processing and Analysis Center, Science and Data Center for Infrared Astronomy, NASA: http://coolcosmos.ipac.caltech.edu/page/lesson_herschel_experiment

Name_____

Discovering Infrared Light Worksheet

DATA/OBSERVATIONS

Record the temperature of the three thermometers in the shade or away from the light (indoors)

	Thermometer #1 (blue)	Thermometer #2 (yellow)	Thermometer # 3 (just beyond red)
Temperature			

Place the thermometers in the box in the spectrum such that one of the bulbs is in the blue region, another is in the yellow region, and the third is just beyond the (visible) red region. Now record the temperatures in each of the three regions of the spectrum: "blue", "yellow" and "just beyond red" after 1, 2, 3, 4 and 5 minutes.

	Termometer # 1 (blue)	Thermometer # 2 (yellow)	Thermometer # 3 (just beyond red)
Temperature at 1 minute			
Temperature at 2 minutes			
Temperature at 3 minutes			
Temperature at 4 minutes			
Temperature at 5 minutes			

Calculate the differences between the final temperatures measured in the spectrum and the temperatures measured away from the light for the three thermometers.

	Thermometer # 1 (blue)	Thermometer # 2 (yellow)	Thermometer # 3 (just beyond red)
Temperature in the spectrum (Tspectrum)			
Temperature in the shade (Tshade)			
Difference (Tspectrum - Tshade)			

Calculate the differences between the final temperatures in each part of the spectrum

Tyellow - Tblue	Tjust beyond red - Tyello	Tjust beyond red - Tblue

Class Average Temperatures
Compute the average final temperature measured by the class in each part of the spectrum.

	Sum of all class temperatures (Tsum)	Total number of obervations (N)	Class Average (Tsum/N)
Yellow			
Blue			
Just Beyond Red			

Compute the average differences measured by the class between the final temperature in the spectrum and the shade temperatures for the three thermometers.

	Sum of class temperature differences (Tsum)	Total number of observations (N)	Class Average (Tsum/N)
Tyellow-Tblue			
Tjust beyond red - Tyellow			
Tjust beyond red - Tblue			

Questions

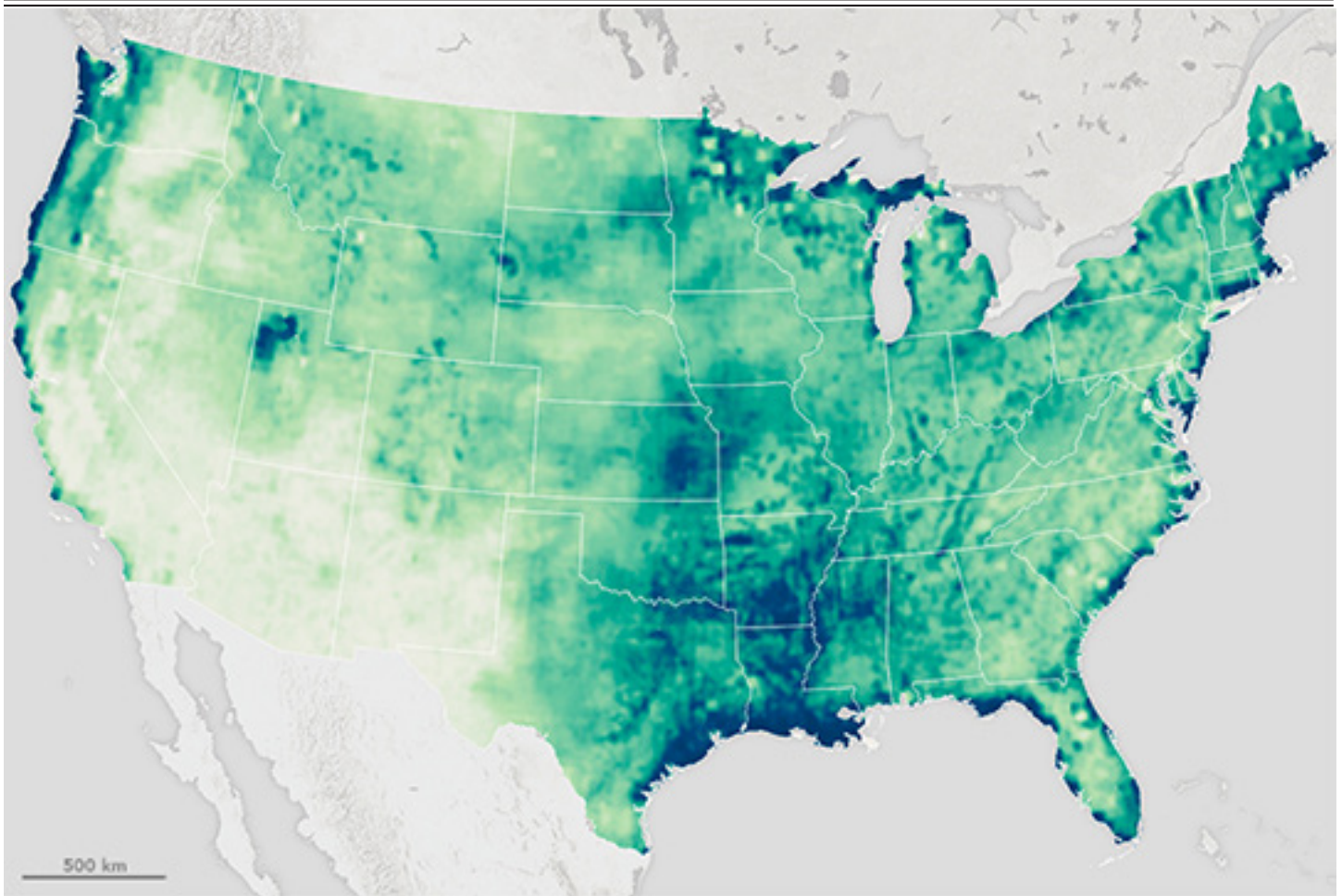What did you notice about your temperature readings?

Did you see any trends?

What was the highest temperature?

What do you think exists just beyond the red part of the spectrum?

Discuss any other observations or problems.

Soil Moisture Map

Soil Moisture (m^3 water/m^3 soil)

0   0.05   0.15   0.25   0.35   0.45   0.55   0.65

  Knowing something about the moisture in the soil is important before, during, and after the growing season. For example, will mud prevent wheat harvesters from getting into the fields? How much water will crops have available at each stage of growth, from germination through harvest? Satellite and ground-based sensors help farmers find out.

  The map above shows the amount of moisture in the top five centimeters of the ground across the US. It was produced with data collected with the radar and radiometer instruments on NASA's Soil Moisture Active Passive (SMAP) satellite during May, 2015. Colors show the volume of water contained in a volume of soil. Dark green and blue areas are progressively wetter, up to a the point of saturation.
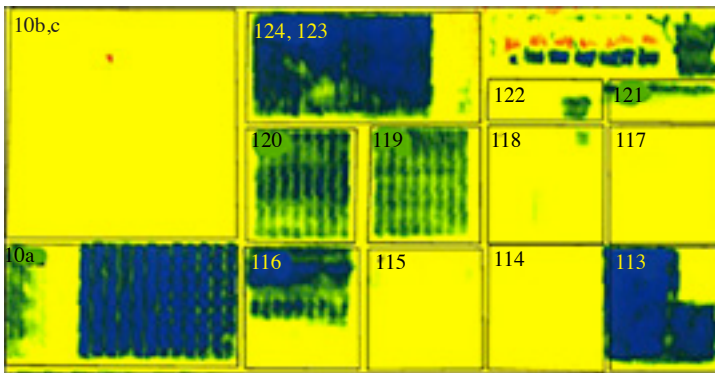
  At the same time, ground-based sensors monitor soil moisture over small areas—typically less than one square meter. There are more than 1,200 ground-based stations across the US.

Source: NASA Earth Observatory, http://earthobservatory.nasa.gov/IOTD/view.php?id=87036
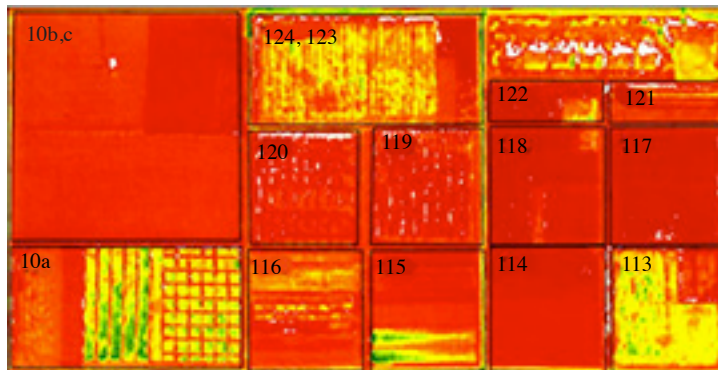
Reading Satellite Images

Satellites use remote sensing instruments to collect data, which is transmitted from the satellite to the ground as radar or microwave signals. Raw satellite data are just sets of numbers registered by digital equipment. By itself, raw data does not make an image. Converting raw data into an image requires computer software that converts ranges of radiation values into "false colors," or colors we can see.
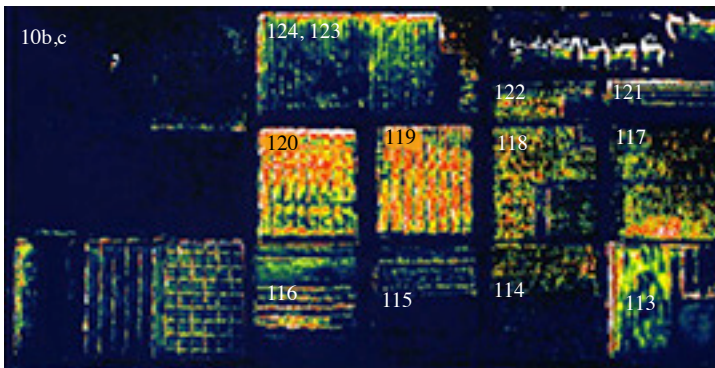
To determine the density of green on a patch of land, researchers observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants. When sunlight strikes objects, certain wavelengths are absorbed and other wavelengths are reflected. The pigment in plant leaves—chlorophyll—strongly absorbs visible light for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light. The more leaves a plant has, the more these wavelengths of light are affected, respectively.

Vegetation Density

Water Deficit

Crop Stress

The images at left are all satellite images of the same section of land.

- The top image shows vegetation density, with the darker colors indicating the most dense vegetation.
- The middle image shows water deficit. Green indicates wet soil and red indicates dry soil.
- The bottom image shows crops under stress, indicated by red and yellow.

For example, a farmer looking at field 119 from all three views would see that the field has a moderate amount of vegetation, is fairy dry and is under stress.

1. In which section is vegetation most dense? Can you tell why by looking at the other images?
2. Why do fields 120 and 119 have stripes?
3. Which fields have crops that are under stress? Why?
4. Which field is the best for growing crops? Why?
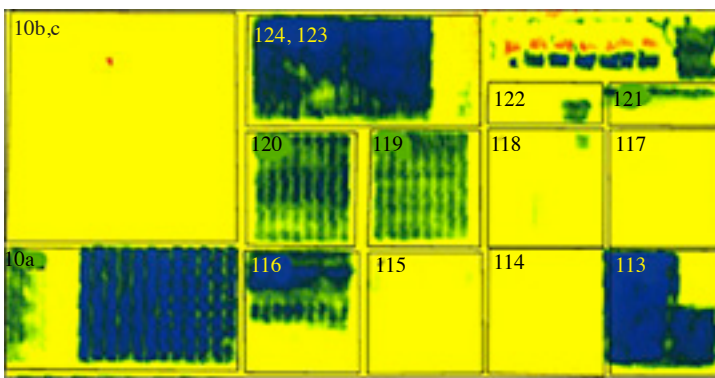5. How would you describe field 10b,c just by looking at the satellite images?

As a group, devise a plan for the best use of this land, based on what you can see from the satellite image. Does it need fertilizer? If so, what? What else does it need?

Sources: http://earthobservatory.nasa.gov/IOTD/view.php?id=1139&src=ve; Susan Moran, Landsat 7 Science Team and USDA Agricultural Research Service

Reading Satellite Images (answers)

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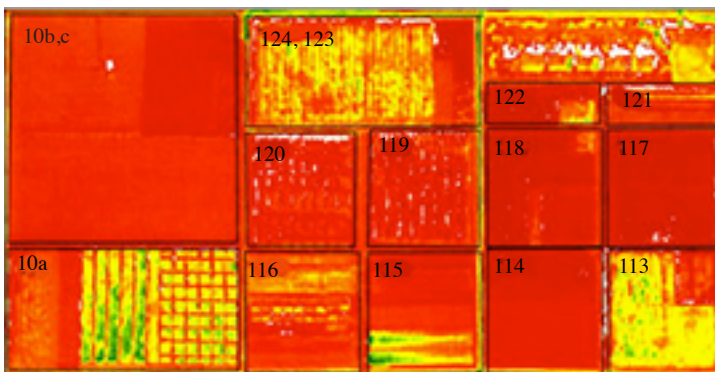

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For example, a farmer looking at field 119 from all three views would see that the field has a moderate amount of vegetation, is fairy dry and is under stress.

1. In which section is vegetation most dense? Can you tell why by looking at the other images? <u>Vegetation is most dense in sections 124, 123; 10a, 116 and 113 because they are the fields that do not have a water deficit.</u>
2. Why do fields 120 and 119 have stripes? <u>The stripes in fields 120 and 119 are probably cultivated rows.</u>
3. Which fields have crops that are under stress? Why? <u>Fields 120 and 119 are under stress because they need water.</u>
4. Which field is the best for growing crops? Why? <u>Field 124, 123 is probably the best for growing crops because it has dense vegetation, doesn't have a serious water deficit and doesn't show very much crop stress.</u>
5. How would you describe field 10b,c just by looking at the satellite images? <u>Field 10b,c has very little vegetion except in one tiny spot (might be a tree), has very little water and no crop stress. It probably is an unplanted field.</u>
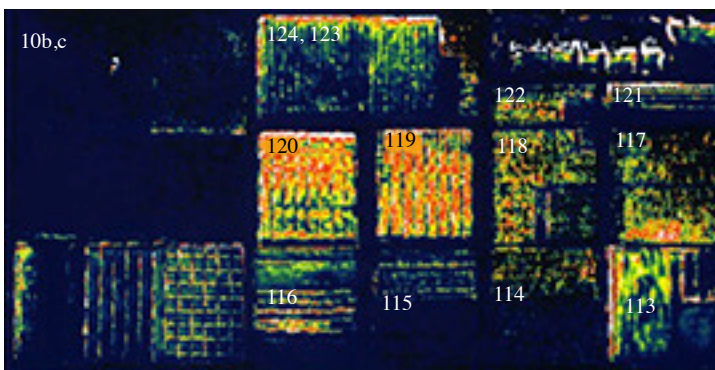
Careers in Ag Technology

New technology helps wheat harvesters and producers with the problem of labor shortage. With new technology workers are still needed, but the jobs often require specialized skills for operating and maintaining complicated equipment. Farm equipment dealers and manufacturers, grain milling operations, research firms, as well as some state and government agencies are all employers looking for employees with knowledge of and skills in the fields of electronics and computer sciences. A sampling of some of the electronics skills required include the following:

- Installation, maintenance and repair of electrical systems
- Reading blueprints and diagrams while troubleshooting and diagnosing electrical problems
- Performing preventative maintenance to avoid operational failures of electrical systems
- Installing electrical wiring, assembling electrical parts and test fixtures and components that provide electricity to related instruments
- Tearing apart and reassembling equipment
- Reading dials and meters to determine amperage, voltage, electrical output and input at specific operating temperature to analyze parts performance
- Remote sensing data collection and management
- Big data mining, including pattern detection, graph analysis, or statistical analyses from a variety of disparate sources.

Use one or more of the career websites listed to locate five job openings related to agricultural electronics and technology. Use the information you find to fill in the blanks below:

- Agriculture and Forestry Careers: http://www.environmentalscience.org/careers/agriculture-and-forestry
- Careers in Agriculture (Georgia Agricultural Education): http://www.gaaged.org/page.aspx?ID=353
- Food, Agriculture and Natural Resources Careers, USDA Living Science, https://www.agriculture.purdue.edu/usda/careers/contactus.html
- MyCAERT, http://www.mycaert.com/career-profiles/
- Occupational Outlook Handbook, Bureau of Labor Statistics, US Department of Labor, http://www.bls.gov/ooh/
- Study.com, http://study.com/article_directory/q_p/page/Agriculture/q_p/Careers_and_Occupations_List.html

Name of Company_____ Location_____

Job Description:

Job Requirements (Education/Training)

Salary Range