LESSON 2: CRITICALLY EVALUATING FOOD PRODUCTION TECHNIQUES

THE BIGGER PICTURE

A variety of agricultural production systems are used to produce food around the world. Some systems rely on the continuous addition of resources, while others use resources more efficiently. In this lesson, students evaluate various food production techniques in terms of their environmental sustainability and potential for producing enough food to feed a growing world population. Students first respond to a video which introduces the inspirational movement of young people using agricultural innovation to address the global food crisis. Students then read articles about five different agricultural production systems, assign sustainability scores to food production techniques, and present their findings. Through teacher-led discussion, the class determines the most sustainable method of food production. Students then justify the best food production technique for the country they investigated in Lesson FS1. Students transition to the next activity (Lab FS1: Creating an Efficient System) by reviewing abiotic and biotic factors needed by each system to produce food.

OBJECTIVES

<u>What students learn</u>

Students deepen their understanding of sustainability in the context of food production and become familiar with the techniques used to grow food. Conventional methods are resource dependent; others may better accomodate our population and changing climate. Solutions are dependent upon regional needs, resource availability, and climate.

<u>What students do</u>

Students respond to the "Thought for Food" video and research 5 food production methods to evaluate their impact and efficiency. Students assign sustainability scores to each method, propose the "best" method in a presentation, and demonstrate understanding by justifying the most effective methods for their assigned country from Lesson FS1.

TIME

60 - 90 minutes (1-2 class periods) depending on optional activities

STANDARDS

- NGSS PE: HS-LS2-7; DCI: LS2.C; SEP: Constructing Explanations and Designing Solutions (CEDS); CC: Stability and Change
- NGSS PE: HS-ESS3-2; DCI: ESS3.A; SEP: Engaging in Argument from Evidence; CC: Influence of Engineering, Technology, and Science (ETS)
- NGSS PE: HS-ESS3-4; DCI: HS-ESS2.C; SEP: CEDS; CC: Influence of ETS
- NGSS PE: HS- ETS1-1; DCI: ETS1.A; SEP: Asking Questions and Defining Problems; CC: Influence of ETS

PREREQUISITES

Students should understand the basic cycles of matter (including the nitrogen cycle) and energy transfer in ecosystems, as well as ecosystem dynamics and functioning. Students should also be familiar with the concept of food security.

BEFORE CLASS

Gather materials (see "Resources" section): "Thought for Food" video, student video guide handout, video teacher key, Food Security Vocabulary powerpoint, Lesson 2 Student Handout (Graphic organizer), Lesson 2 Handout Teacher Key, and Building Your Case worksheets. Students should either have laptops to read the food production system articles or these articles should be printed out prior to class. All of the *Modeling Sustainable Food Systems* resources are on the SEE website: see.systemsbiology.net.

TEACHER INSTRUCTIONS

1. **Warm-Up:** Students come up with a definition for sustainability, which will provide a framework within which they can evaluate the different food production systems.
   - Show the vocabulary for Lesson 2 using the Food Security Vocabulary PowerPoint. Have students brainstorm the meaning of "sustainability". Show the 3 Pillars PowerPoint to refresh students' memories of food security, and ask students to discuss how food security might be related to sustainability. The purpose of this lesson is to learn about different agricultural systems and to evaluate their degree of sustainability, while keeping in mind the connection between agriculture and food security.
   - **Definitions:**
     - <u>Sustainable Development:</u> "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987)
     - <u>Sustainable:</u> "Of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged" (Merriam-Webster dictionary)
2. **Optional Activity - defining the problem:** Through watching a 20-minute inspirational video, students learn more about the global food crisis and how young people are coming up with innovative ways to improve our current methods of food production.
   - Pass out the video guide for "Thought for Food" (see Resources), and have students preview the questions.
   - Show "Thought for Food" (~20 minutes), a documentary on young innovators tackling the challenge to feed 9 billion humans.
   - After watching the video, ask students to name some of the main challenges we are facing with our current food production, based on what they already know or what they learned in the film (e.g. water storage, land shortage, agricultural runoff, population growth, etc). How do these challenges affect food security? Which of the 3 Pillars of food security discussed in FS Lesson 1 are the innovation teams each addressing?
3. **Transition to the next activity,** by asking students to discuss the following:
   - What are the ways in which we currently produce food? They may mention factory farms, commercial agriculture, organic farms
   - Review: What are the basic resources necessary for producing food? Land, soil, sunlight, nutrients, water, etc.
   - What are some criteria we could use to decide how successful and efficient an agricultural system is? What do you think an ideal food production system would look like?

TEACHER INSTRUCTIONS CONTINUED

4. **Activity 1 - understanding current food production systems:** Students read about five different categories of agricultural production, and then evaluate, present, and discuss the sustainability of each agricultural system. If teachers wish to save class time, a homework option is described below in which students are assigned the reading for homework rather than completing it in class.

- Handout the "Graphic organizer 1: Comparing Food Production Systems" worksheet to the students, and review with them what an "optimal" food production system would look like. Compare the list on the worksheet to the criteria the students brainstormed with after the "Thought for Food" video.
- Ask the students to think about whether or not our "optimal" food production system might look different in different geographical areas. For example, how might the climate of a region impact the type of farming methods used there?
- As a class, read the following articles about small farms/traditional farming (Group 1): http://www.wildmadagascar.org/overview/loc/36-agriculture.html; https://casfs.ucsc.edu/about/publications/Teaching-Direct-Marketing/pdf%20downloads/Unit.1.pdf (pgs. 5-7)
- Calculating the sustainability scores: With student input, fill in the first column "Small/Traditional Farms" of the "Graphic organizer 1". Each criteria should be assigned a number as follows: 1 = high level of sustainability, 2 = medium level of sustainability, 3 = least sustainable. For this exercise, sustainability of a food production system means it both produces a high quantity of food while simultaneously maintaining the health of the environment. Add up the numbers in a column to obtain the overall sustainability score for a particular food production system. The lowest overall value will determine the most sustainable food production system.
- Break the students up into groups of 2-4. Assign each group (or let them choose) one of the four remaining agricultural methods to read about. Each student group should then read the article(s) associated with their specific food production system (see links below), and fill in the appropriate column of the "Graphic organizer 1". Some of their articles may provide information on other agricultural production systems, so they should fill in other areas of the chart if possible. Tell the students that the articles might not provide them answers to every criteria, they may need to infer a value from the text. Also, they should read all of the articles and annotate them before they choose a value for a particular criteria. Finally, be clear with the students that the articles that they are reading may be biased, depending on the source the information is coming from. Discuss with the students: "What is the value of reading potentially biased articles, and how do we remain objective while we are doing so?" (This question will hopefully generate discussion about how it is important be open to different ideas and perspectives. Staying objective will involve taking into consideration the source, cross-checking information, overcoming one's own bias, and referring to peer-reviewed scientific articles for further information.)
- The answers to the Graphic Organizer 1 table can be found in "Lesson 2 Teacher Key" (see Resources). However, there are not necessarily any "correct" answers to the graphic organizer. If a student can justify their values based on the reading, then it is "correct".
- Homework option: Instead of having students read their articles during class time, teachers can assign the article reading as homework, in addition to filling out the Graphic Organizer 1 for a particular food system. The small/traditional farming group 1 reading can also be assigned to a group instead of read by the whole class. The teacher can resume discussion of the chart with the class the following day.

Group reading articles:

Group 2: Native/Organic Farming
- http://organic-farming.farm/
- https://www.scientificamerican.com/article/organic-farming-yields-and-feeding-the-world-under-climate-change/
- http://www.cnn.com/2017/03/22/opinions/organic-farming-conversation/index.html

Group 3: Industrial/Commercial Farming
- http://www.sdsoybean.org/scoop-on-soybean-blog/a-visit-to-the-largest-soybean-farm-in-the-world/
- http://www.globalharvestinitiative.org/Documents/Motes%20-%20Modern%20Agriculture%20and%20Its%20Benefits.pdf (pgs. 12-16)
- http://psep.cce.cornell.edu/facts-slides-self/facts/mod-ag-grw85.aspx

Group 4: Hydroponics
- http://web.mit.edu/12.000/www/m2015/2015/hydro_agriculture.html
- https://www.maximumyield.com/hydroponics-pros-and-cons-of-hydroponic-gardening/2/3049
- https://www.theguardian.com/environment/2016/aug/14/world-largest-vertical-farm-newark-green-revolution

Group 5: Aquaponics
- https://cdn.shopify.com/s/files/1/0941/8606/files/Curriculum_Unit2_WG_9a283ab6-af9e-4f16-a89a-8effaf126f67.pdf?16617835315743887852
- https://www.researchgate.net/publication/303186885_Aquaponics_and_its_potential_for_food_security_in_Kenya
- https://www.nasa.gov/audience/foreducators/9-12/features/aquaponics.html

- Once all the groups have finished reading their articles and filling in their appropriate column, have each group present their findings to the class. All groups should complete the chart as the different agricultural systems are presented. They can present their information verbally, or they could create a poster.
- Discuss the following questions with the class, related to their findings from the table:
  1. Were there any categories that you had difficulty scoring for your particular system? This question will hopefully start a discussion about how there is a lot of diversity of farm types within each of these categories.
  2. Do you think the sustainability score is an accurate representation of the value of a certain production system? Why or why not? What else might you incorporate into a sustainability score? Some ideas that might surface include use of genetically-engineered seed, food quality, cost to the consumer, etc.
  3. What are some differences in the types of foods that each system produces? The scoring system doesn't evaluate the quality of the food produced, and this could be an important consideration. Organic food might be slightly more nutritious, and aquaponics is highly valuable in that it produces protein in addition to carbohydrates.
  4. Do any of the agricultural production methods have an optimal sustainability score? Is this production method in fact "ideal"? Why or why not? Aquaponics may come up with a perfect score, but the initial start-up cost might not be feasible in some cases.
  5. Can you think of geographical variables that might make one system more optimal than another, regardless of the sustainability score? For example, aquaponics would be a good fit for an arid environment because of its low water usage, but organic farming might be a better alternative in very poor, rural areas where funding is an issue and power outages occur.

TEACHER INSTRUCTIONS CONTINUED

5. **Activity 2 - designing a solution:** In this third part of the lesson, students use their knowledge of the different food production systems to propose how to produce enough food, sustainably and efficiently, for the same country they investigated in FS Lesson 1 (Haiti, North Korea, or Namibia).
- Students now re-form the three country groups they worked in during FS Lesson 1, and fill out questions 1 and 2 in the Lesson 2 section of the "Building Your Case" worksheet
- Encourage students to consider/remember the following as they design a solution for their country's food insecurity situation:
  - What are the country's limiting natural resources? Soil? Water?
  - Are there political or socio-demographic factors that influence the food security? How will those be surmounted in your solution?
  - How will food be transported to people who need it?
  - How will food be produced throughout the year, beyond the growing season if there is one?
  - Are there other climatic issues that need to be considered in your solution?
  - Would different food production systems work better for different parts of the country?
- Have the students present their solution to the rest of the class, either verbally or in poster form depending on available time.

6. **Formative Assessment/Exit Ticket:** In this final part of Lesson 2, the class finds similarities between the different food production systems by examining the environmental inputs necessary for all agricultural systems. The goal is to transition the students into "FS Lab 1: Creating an Efficient System" in which they will make their own aquaponic system.
   - Ask students to reflect about the following: we've talked about differences in agricultural production techniques. What do these systems have in common? Write their answers on the board as they brainstorm.
   - Have students quickly fill out (yes or no) the "Agricultural Necessities Chart" on the Lesson 2 Student Handout, and compare answers. It should be clear that all agricultural systems need certain biotic and abiotic factors, although hydroponics and aquaponics are slightly different in that they do not require soil and may not require sunlight if run on artificial lighting. Answers for this chart can be found in the "Lesson 2 Graphic Organizer & Chart Teacher Key" (see Resources).

EXTENSION ACTIVITY - READING SCIENTIFIC LITERATURE

This optional extension activity gives students the opportunity to practice reading scientific literature and making claims based on data. This activity can be assigned as homework after Lesson 2 or can be a practice activity as students prepare for Free Response Questions (FRQs) in AP courses.

- Read the following scientific paper and compare the sustainability of three apple farming systems: http://www.nature.com/nature/journal/v410/n6831/abs/410926a0.html
- Read the following scientific review of the need for sustainability in addressing food insecurity: https://www.nature.com/nature/journal/v418/n6898/pdf/nature01014.pdf

FURTHER BACKGROUND

Due to the student readings for this lesson being based on internet sources, some may expire. Below are additional links for each agricultural production system. In addition, several overview sources on sustainability and agricultural systems are provided.

Overview articles/books: sustainability and agricultural systems:
- https://www.nature.com/nature/journal/v418/n6898/pdf/nature01014.pdf
- http://www.agcensus.usda.gov
- http://www.fao.org/agriculture-consumer-protection-department/en/
- http://www.worldbank.org/en/topic/agriculture
- Book: "The Omnivore's Dilemma", Michael Pollan

Small/Traditional Farms:
- http://www.history.com/news/hungry-history/thomas-jefferson-americas-pioneering-gourmand
- https://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Farm_Numbers/small_farm.pdf

Organic agriculture overview:
- http://kerrcenter.com/wp-content/uploads/2014/08/organic-philosophy-report.pdf
- http://www.sare.org/Learning-Center/Bulletins/Transitioning-to-Organic-Production/Text-Version/What-is-Organic-Farming
- https://www.usda.gov/media/blog/2011/04/26/organic-farm-provides-model-new-mexico

Commercial agriculture overview:
- https://www.nature.org/ourinitiatives/regions/southamerica/brazil/explore/brazil-china-soybean-trade.pdf
- http://www.economist.com/technology-quarterly/2016-06-09/factory-fresh

Hydroponics:
- http://www.simplyhydro.com/whatis.htm
- http://www.powerhousehydroponics.com/4-commercial-vertical-farms-worth-attention/
- http://www.economist.com/node/17647627

Aquaponics:
- http://www.developonics.com/wp-content/uploads/2017/04/Aquaponics-in-Namibia-WUR.pdf
- http://ase.tufts.edu/water/pdf/Practicum_Andros_FinalReprt_2015.pdf
- http://freshfarmct.org/about/

RESOURCES

- SEE website: see.systemsbiology.net
  - Food Security Vocabulary PowerPoint
  - 3 Pillars PowerPoint
- Student "Thought for Food" video guide handout
- Teacher "Thought for Food" video teacher key
- Lesson 2 Student Handout - Graphic Organizer 1 & Chart
- Lesson 2 Graphic Organizer & Chart Teacher Key
- "Building Your Case" worksheet
- "Thought for Food" video: http://www.tffchallenge.com/watch-us/documentary/

RESOURCES: STUDENT HANDOUT - THOUGHT FOR FOOD VIDEO GUIDE

1. What is the main idea behind the video?

2. As a global society we used to only have to feed 2 people off of a hectare of land, we now need to feed _________ people.
3. Food for thought runs a challenge each year to generate ideas, over 100 teams entered ___________ were chosen as finalists.

Team Agrilution-The Netherlands

4. What is vertical farming?

5. How will it help with securing food?

6. How are they also helping with water conservation?

7. Name two benefits of using a greenhouse to grow food.

8. Why is the team using both red and blue lights to grow their food?

Team Oasis- Kenya

9. Women in Sub Saharan Africa spend more than ______ billion hours collecting water each year.
10. Of all the water on Earth, ____% is in the seas, leaving only _____% of fresh water, of which only about _____% is available.
11. What is team oasis' idea?

Team Henlight- California

12. What aspect of food production is team henlight trying to increase?

13. How is egg production in chickens and the time of year (season) related?

14. How will the henlight help to increase production?

Team Five Loaves- Nebraska

15. What issue is team five loaves focusing on?

16. What is their plan to get it done?

17. What is the economic benefit to the restaurants involved?

Team Ingenerovictus- India

18. What issue are they focusing on?

19. What products will their plan generate?

20. If you were one of the judges in the competition which project would you choose to win? Why? (Justify your answer)

21. The winner of the global summit is ____________________!

If you are interested in generating a team to compete in the next Thought for Food challenge, go to http://www.tffchallenge.com/challenge for information.

RESOURCES: TEACHER - THOUGHT FOR FOOD VIDEO TEACHER KEY

1. What is the main idea behind the video? To highlight the growing concern over our lack of food security. We will need to feed 9 billion people by 2050.
2. As a global society we used to only have to feed 2 people off of a hectare of land, we now need to feed ______5____ people.
3. Food for thought runs a challenge each year to generate ideas, over 100 teams entered _______5_____ were chosen as finalists.

Team Agrilution-The Netherlands

4. What is vertical farming? Farming using the vertical space, as a way of cutting down on the amount of land being used to produce the same amount of goods. A lot of times, this is done using greenhouses. Farm in stacks.
5. How will it help with securing food? Able to use less land, while still producing as much food.
6. How are they also helping with water conservation? Being able to minimize the amount of water being used, by recycling the water.
7. Name two benefits of using a greenhouse to grow food. Able to control light, CO_2, nutrients, water, humidity. You also do not have to worry about pests, other animals, or the weather as much.
8. Why is the team using both red and blue lights to grow their food? These are the two wavelengths of light most absorbed by plants. Then plants reflect back green wavelengths as a part of the visible light spectrum. Using the red and blue lights, optimizes the light energy being given to the plants or a higher yield in crops.

Team Oasis- Kenya

9. Women in Sub Saharan Africa spend more than ___40___ billion hours collecting water each year.
10. Of all the water on Earth, __97__% is in the seas, leaving only ___3__% of fresh water, of which only about ___~1__% is available.
11. What is team oasis' idea? Being able to build structures, that people can live in, that will also be used to turn salt/ rain water into drinkable water using evaporation and condensation techniques.

Team Henlight- California

12. What aspect of food production is team henlight trying to increase? Eggs
13. How is egg production in chickens and the time of year (season) related? Chickens produce more eggs during the summer time, when the hours of light in the day is more.
14. How will the henlight help to increase production? By using solar power to supply energy to the device during the day, when there is a lack of light, the device will power on. This will help trick the light sensors in the brain of the chickens that the day is actually longer, so they will continue to produce eggs.

Team Five Loaves- Nebraska

15. What issue is team five loaves focusing on? Trying to highlight the fact that some people get too much to eat, while others are starving. Focusing on balancing out calories for each side.
16. What is their plan to get it done? Talk to local restaurants about a featured, healthy meal. When someone orders that meal, the restaurant donates 25 cents to Five Loaves, they will in turn use the money to help support an organization that globally is focused on food security.
17. What is the economic benefit to the restaurants involved? Additional advertising. They are also highlighted for their healthy options.

Team Ingenerovictus- India

18. What issue are they focusing on? The overwhelming amount of food waste produced, especially in India. The are working with local restaurants to collect their food waste.
19. What products will their plan generate? From the food waste they will generate biofuel and manure.
20. If you were one of the judges in the competition which project would you choose to win? Why? (Justify your answer)
21. The winner of the global summit is _______henlight_______________!

If you are interested in generating a team to compete in the next Thought for Food challenge, go to http://www.tffchallenge.com/challenge for information.

RESOURCES: STUDENT HANDOUT - GRAPHIC ORGANIZER 1 & AGRICULTURAL NECESSITIES CHART

GRAPHIC ORGANIZER 1: COMPARING FOOD PRODUCTION SYSTEMS

Directions: Read through the articles assigned to your group. Using the information from the articles, as well as what you already know about your agricultural production system, fill in the following chart with your partner. For each criteria (e.g. water use, nutrient addition), you need to assign your food production technique a value of 1, 2, or 3: 1 = most sustainable, 2 = medium level of sustainability, 3 = least sustainable. A high sustainability score means high food productivity while maintaining the health of the environment. The articles may not provide you with all the information you need to fill out the chart, in which case you will need to think about how your food production technique works overall and infer a value. We will calculate the sustainability scores as a class.

	SMALL/ TRADITIONAL FARMS	NATIVE/ ORGANIC FARMING	INDUSTRIAL/ COMMERCIAL FARMING	HYDROPONICS	AQUAPONICS	OPTIMAL SCORE
WATER USE						
NUTRIENT ADDITION						
FOOD PRODUCTION						
ARABLE LAND/ SPACE REQUIREMENT						
OVERALL COST						
ENVIRONMENTAL IMPACT						
ENERGY USE						
SUSTAINABILITY SCORE						
OVERALL SYSTEM DESCRIPTION						
ADDITIONAL SYSTEM NOTES						

AGRICULTURAL NECESSITIES CHART

Directions: Write "Y" or "N" in the boxes below to indicate whether or not an agricultural system requires a particular biotic or abiotic factor to be productive.

	NUTRIENTS	WATER	SOIL	NITROGEN-FIXING BATERIA	SUNLIGHT	CARBON DIOXIDE
SMALL/TRADITIONAL FARMS						
NATIVE/ORGANIC FARMING						
INDUSTRIAL/ COMMERCIAL FARMING						
HYDROPONICS						
AQUAPONICS						

RESOURCES: GRAPHIC ORGANIZER AND AGRICULTURAL NECESSITIES CHART TEACHER KEY

GRAPHIC ORGANIZER 1: COMPARING FOOD PRODUCTION SYSTEMS

Directions: Read through the articles assigned to your group. Using the information from the articles, as well as what you already know about your agricultural production system, fill in the following chart with your partner. For each criteria (e.g. water use, nutrient addition), you need to assign your food production technique a value of 1, 2, or 3: 1 = most sustainable, 2 = medium level of sustainability, 3 = least sustainable. A high sustainability score means high food productivity while maintaining the health of the environment. The articles may not provide you with all the information you need to fill out the chart, in which case you will need to think about how your food production technique works overall and infer a value. We will calculate the sustainability scores as a class. (For the teacher: **black lettering** = discuss as a class; red lettering = students fill these in while reading their articles)

	SMALL/ TRADITIONAL FARMS	NATIVE/ORGANIC FARMING	INDUSTRIAL/COMMERCIAL FARMING	HYDROPONICS	AQUAPONICS	OPTIMAL SCORE
WATER USE	2	2	3	1	1	1
NUTRIENT ADDITION	1 - 3	1	3	2	1	1
FOOD PRODUCTION	2 - 3	2 - 3	1	1	1	1
ARABLE LAND/ SPACE REQUIREMENT	2	2	3	1	1	1
OVERALL COST	1 - 2	2	2 - 3	2	2	1
ENVIRONMENTAL IMPACT	2 - 3	1	3	1	1	1
ENERGY USE	1 - 2	1	3	3	2	1
SUSTAINABILITY SCORE	11-17	11 - 12	18-19	11	9	7
OVERALL SYSTEM DESCRIPTION	Huge diversity of farms, ranging from slash-and-burn agriculture in developing countries to farms that earn <$250,000 profit in the US.	Food is grown in an environmentally sustainable way using techniques such as crop rotation, composting, and integrated pest management.	Large-scale farming that focuses on producing large amounts of food using synthetic fertilizers, pesticides, machinery, and often genetic engineering	Plants are grown directly in water and are provided nutrients directly, rather than absorbing them from soil.	Combines aquaculture with hydroponics by using the waste of aquatic organisms to fertilize plants.	
ADDITIONAL SYSTEM NOTES						

AGRICULTURAL NECESSITIES CHART

Directions: Write "Y" or "N" in the boxes below to indicate whether or not an agricultural system requires a particular biotic or abiotic factor to be productive.

	NUTRIENTS	WATER	SOIL	NITROGEN-FIXING BATERIA	SUNLIGHT	CARBON DIOXIDE
SMALL/TRADITIONAL FARMS	Y	Y	Y	Y	Y	Y
NATIVE/ORGANIC FARMING	Y	Y	Y	Y	Y	Y
INDUSTRIAL/COMMERCIAL FARMING	Y	Y	Y	Y	Y	Y
HYDROPONICS	Y	Y	N	Y	Y/N	Y
AQUAPONICS	Y	Y	N	Y	Y/N	Y