engineering DREAMS

CREATE YOUR BEST WORLD

ACTIVITY

Soilless Farming

OBJECTIVES

Students will:

- **Define** the concept of sustainable agriculture.
- **Perform** research to understand the environmental impact of traditional agricultural practices.
- **Identify** and **analyze** existing sustainable agriculture solutions.
- **Design** their own sustainable agriculture solution.

GRADE RANGE

5–9

DURATION

One class session (approximately 60 minutes)

OVERVIEW

Agriculture plays a huge role in the world's economy and is responsible for most of the world's food and fabrics. However, in many countries around the world it is also the largest source of pollution. Farming often produces excess food waste, and toxins used in traditional agriculture can harm water, air, soil, and ecosystems. Thankfully, solutions to make agriculture more sustainable and environmentally friendly do exist.

To better understand this problem and empathize with those whom it affects, students will research the global effects of traditional agricultural practices. Considering the UN's Sustainable Development Goals, students will determine how many goals could be advanced through sustainable agriculture. They will then research solutions to this global problem as they learn about close-looped and soilless (hydroponic) farming. They will ultimately design a sustainable agriculture solution that illustrates how their family or community could implement hydroponic farming on a smaller scale.

MATERIALS

- Internet device with ability to project video, one for the educator
- Device with internet access, one per student
- **Achieving Sustainable Agriculture** student handout, one per student
- **What is Sustainable Agriculture?** student handout, one per student
- **Hydroponic Solutions** student handout, one per student
- **Hydroponics Examples** handout, one for the educator to project or share with the class
- Bottle of liquid nutrients, one per educator
- *Design and Build* materials, one per student:
  - Empty and clean 2-liter bottle (individual water bottles work too)
  - Permanent marker
  - Scissors or utility knife
  - 2 cotton strips, approximately 6” long
  - Hydroponic growing medium (rocks, gravel, perlite, rockwool, sand)
  - Large container with spout
  - 1 quart of water
  - Small lettuce plant (most herbs work well too)

PROCEDURE

Engage

1. Begin with a class graffiti wall. Write “Agriculture” in large letters in the center of the board and call up students in small groups to write and/or illustrate what comes to mind when they see this word.
2. Once all students have a chance to record their ideas, explain that agriculture is the process of growing crops and raising livestock. Agriculture is responsible for most of the world’s food and fabrics.
3. Go on to explain that *what* is produced and *how* it is produced varies on the location. However, globally, one of the agricultural sector’s biggest challenges is figuring out how to feed a growing population while reducing its environmental impact. Today, students will lend a hand as they contribute to solving this problem.

4. Distribute one **Achieving Sustainable Agriculture** handout to each student. Read through the *Define the Problem* section together. Kick off the activity by either reading together or having students read independently the **What is Sustainable Agriculture?** article distributed by the Sustainable Agriculture Research and Education (SARE) program of the USDA.
5. Instruct the class to complete numbers one through three independently or with a partner. Explain that before trying to find a solution, it is important to understand the problem.
6. Once about ten minutes has passed, bring the class back together. Discuss: What are some of the biggest environmental challenges of traditional agriculture?

Learn

7. Explain that there are many different initiatives focused on making farming sustainable and beneficial for the environment. For instance, an organization called Re-Nuble takes advantage of food waste! In order for students to contribute to solving this problem, it is important for them to be aware of the alternatives to traditional agriculture that already exist.
8. Play the *Problem Solvers for Good: Making the World a Better Place Through Engineering* video featuring Re-Nuble and encourage students to listen for this organization's innovative solution. (https://engineeringdreamsinschool.com/educators/video-topic-series/)
9. Then bring students' attention to the *Perform Background Research* section of their handout and review the instructions. Then give the class about ten minutes to complete this section.
10. Bring the class back together and discuss: How do these innovations address some of the environmental challenges of traditional agriculture?

Apply

11. Now bring students' attention to the *Evaluate and Ideate* section of their handout. Explain that students will apply what they have learned and continue to explore possible solutions as they further investigate the concept of hydroponic farming.
12. Distribute a **Hydroponic Solutions** article, published by the Center for Agriculture, Food, and the Environment at the University of Massachusetts Amherst, to each student to either read as a group or independently. Provide the class a few minutes to answer the section's first question.
13. Next, challenge the class to evaluate how these existing solutions could lessen farming's environmental impact *and* guide the class toward ideating their own solutions. Facilitate this by leading the class in a discussion* around the following questions. Encourage students to take notes on their handout as they participate in the conversation.
    - **Discussion Question 1:** Think about the environmental impacts of traditional agriculture and how hydroponic farming may help. Which Sustainability Goal(s) could hydroponic farming positively impact?
    - **Discussion Question 2:** Who in the world could benefit from hydroponic farming? Why?

- **Discussion Question 3:** In what ways could individual people or families use hydroponic principles to grow their own food? To make this possible, could you adapt a solution that already exists? Or could you engineer a brand-new solution?

  - *Note:* *If you prefer to have students complete this section individually, they may develop and record answers to the handouts independently or in pairs without participating in a class discussion.*

Challenge

14. Explain that now that students have defined the problem, performed background research, and ideated and evaluated, it's time to design and build a potential solution.
15. Bring students' attention to the *Design and Build* section of their handout and tell the class that their challenge will be to apply what they have learned to build a small-scale hydroponic farming system that they can use to grow lettuce or herbs.
16. Read through the instructions together and answer any questions as they arise. Show students where the materials are located and let them begin. Note that additional adult supervision will be required for steps 2 and 6.

Discuss

Note: *This section can be completed in class as time allows, in a follow-up session, or as an at-home/ extension activity.*

17. Encourage students to review the work they have completed. Remind them that the engineering design process is always represented as a circle and not a straight line. To develop a solution that works, engineers often must refer back to the very beginning!
18. Then encourage the class to complete the final *Innovate and Reiterate* section of their handout. Considering what they have learned by creating a small-scale hydroponic system for a vegetable plant, how can they improve upon this design or come up with a better one that can be produced on a larger scale to serve the community?
    - **Note:** *If students are having difficulty conceptualizing other hydroponic systems, share the* ***Hydroponics Examples*** *handout to jumpstart the design process.*

Reflect

19. Once students have designed a solution, facilitate students' reflection on their learning by inviting them to summarize how hydroponic farming and their innovative designs can help achieve sustainable agriculture.
20. If time allows, encourage students to share their unique design ideas with their peers. Small groups may compare and contrast their designs with each other so that students can then optimize their designs.

LEARNING EXTENSIONS

- Students may use their **Achieving Sustainable Agriculture** handout to build a prototype of their initial design in school or at home. Encourage them to record their successes and failures, as well as make improvements to their designs.
- Your class may collaborate to build and maintain a vertical garden or hydroponic garden system. The produce can then be donated to help feed your school, students' families, local food pantries, homeless shelters, etc.

NATIONAL CONTENT STANDARDS

Next Generation Science Standards

Engineering Design:

- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Earth and Human Activity:

- MS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Standards for Technological Literacy (ITEAA Standards)

Standard 1: Students will develop an understanding of the characteristics and scope of technology. In order to comprehend the scope of technology, students should learn that:

- F. New products and systems can be developed to solve problems or to help do things that could not be done without the help of technology.
- G. The development of technology is a human activity and is the result of individual or collective needs and the ability to be creative.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology. In order to recognize the changes in society caused by the use of technology, students should learn that:

- D. The use of technology affects humans in various ways, including their safety, comfort, choices, and attitudes about technology's development and use.

Standard 8: Students will develop an understanding of the attributes of design. In order to comprehend the attributes of design, students should learn that:

- E. Design is a creative planning process that leads to useful products and systems.
- G. Requirements for a design are made up of criteria and constraints.

Common Core English Language Arts Standards

Reading:

- R.7: Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.

Writing:

- W.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- W.7: Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

Speaking & Listening:

- SL.1: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

Define the Problem

1. Read the "What is Sustainability?" article. As you do, look for information answering: What is sustainable agriculture? How can it be achieved? Record notes below:

2. Visit https://wwf.to/3DU9SDz and look for details that help you understand how traditional farming can negatively impact the environment. Record notes below:

3. The United Nations has developed 17 Sustainable Development Goals that are designed to be a "blueprint (or plan) to achieve a better and more sustainable future for all."

   Visit https://sdgs.un.org/goals and briefly review the goals. Which goals may be threatened by farming's negative effects?

Perform Background Research

1. You just watched a video about Re-Nuble, which is one existing solution for sustainable agriculture. Visit www.re-nuble.com to learn more about this organization and its agricultural innovation.

   Below, further explain the problem that Re-Nuble is trying to solve and how it tries to solve this problem:

2. What other organizations or products are trying to solve this problem in a similar way? Perform your own internet research and try to find at least two other similar solutions. Explain their solutions briefly below:

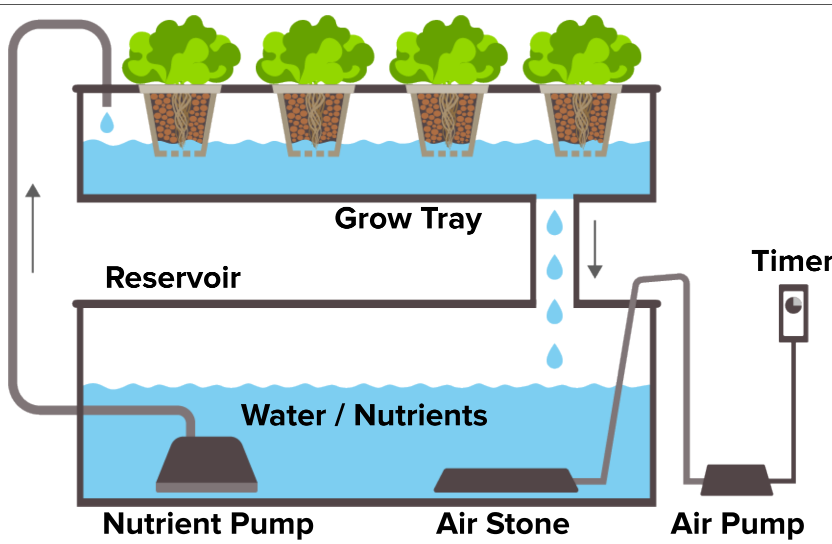
Ideate and Evaluate

1. **Read & Jot:** Read the "Hydroponic Systems" article and use what you learn to make sense of the infographic below. Then in the space provided, summarize how hydroponic farming works.

2. **Discuss & Jot:** Think about the environmental impacts of traditional agriculture, and how hydroponic farming may make a difference. Which Sustainability Goal(s) could hydroponic farming help with?

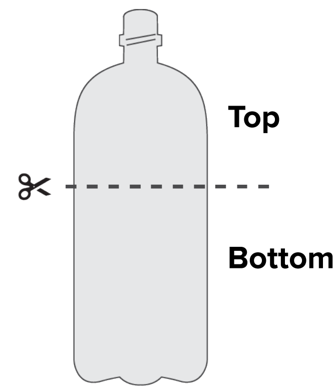
3. **Discuss & Jot:** Who in the world could benefit from hydroponic farming? Why?

4. **Discuss & Jot:** In what ways could individual people or families use hydroponic principles to grow their own food? To make this possible, could you adapt a solution that already exists? Or could you engineer a brand-new solution?

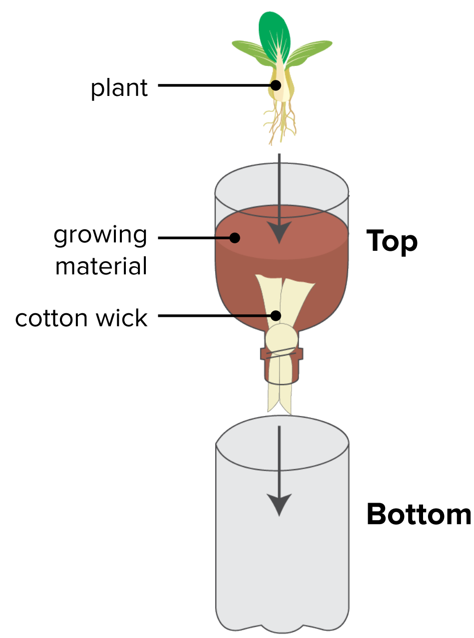


Design and Build

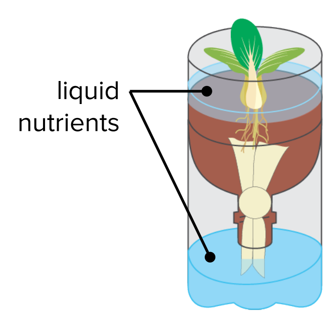
Procedure



1. Use the permanent marker to draw a line around the 2-liter bottle just under where the cylinder starts to curve towards the cap.
2. Use your scissors or utility knife to cut along the line, creating two pieces.
3. Pull the two pieces of cotton through the spout. Inside the top part, tie the two pieces into a large knot that keeps it from falling through the hole when you flip it upside down. This will serve as the wick that brings water to the roots of your plant.
4. Flip the top upside down and put it inside the bottom part of the bottle. The top will be where you grow your plant, and the bottom will be where you store your water.



5. Fill the top portion with hydroponic growing material. Make sure that as you fill it, your wick is pulled about 2/3 of the way up into the medium.
6. Put on your gloves and pour the water into the second container. As your teacher comes around with the liquid nutrients, add the required amount to the water.
7. Place your plant into the growing medium with the roots close to the wick. Be gentle! You don't want to damage your roots.
8. Pour your prepared nutrient water over the growing medium until your reservoir at the bottom is 1/2 to 2/3 full. Make sure it doesn't reach the spout of the upside-down bottle!
9. Place your plant near a sunny window and wait for it to grow! Check the water level in your reservoir weekly and adjust as needed.



Innovate and Reiterate

In the space below, design one way that an individual person or family could implement hydroponic farming principles in your community on a larger scale. Your idea may be an improvement to an existing product or method, or it may be an entirely new idea. Be sure to label your design as you illustrate your solution as clearly as possible.

Photo by Troy Bishopp

what is SUSTAINABLE agriculture?

Every day, farmers and ranchers around the world develop new, innovative strategies to produce and distribute food, fuel and fiber sustainably. While these strategies vary greatly, they all embrace three broad goals, or what SARE calls the 3 Pillars of Sustainability:

PROFIT over the long term
STEWARDSHIP of our nation's land, air and water
QUALITY OF LIFE for farmers, ranchers and their communities

There are almost as many ways to reach these goals as there are farms and ranches in America.

A cattle rancher might divide his rangeland into paddocks in a rotational grazing system to better manage soil and water resources while improving animal productivity. A field crop farmer might implement a rotation to break up pest cycles, improve soil fertility and cut costs, or use cover crops—non-cash crops grown for their benefit to the soil and ability to suppress weeds. A fruit and vegetable grower might try a new marketing approach such as selling directly to restaurants in a nearby city to gain a larger share of the consumer food dollar.

No one recipe works on every farm and ranch. But to give a flavor of sustainable agriculture at work, we have profiled the sustainable operations of eight of SARE's many cream-of-the-crop grantees—including producers, researchers and educators. To get a more complete picture, view 61 in-depth profiles in SARE's book *The New American Farmer, 2nd edition* at www.sare.org/newfarmer.

Best Practice Sampler

It is impossible to list all the innovative and varied practices farmers and ranchers use to improve sustainability, so consider SARE's list below a sampling, not a prescription, of best practices.

MARKETING

Farmers and ranchers can boost their financial sustainability by using a greater diversity of marketing techniques: processing on-farm; creating value-added products and a strong brand identity; conducting market research to match product to demand; selling direct to consumers at farmers markets, community-supported agriculture (CSA) enterprises, roadside stands or through the Web; and delivering to restaurants, small grocers and local institutions—to name just some techniques.

SARE
Sustainable Agriculture
Research & Education

Cover photos: (from top) see p. 6; see p. 11; see p. 4; see p. 7; Courtesy Santa Cruz Farm; see p. 8; see p. 9; see p. 10. **Credit:** Design, Kirsten Ankers. Editing/Production, Dena Leibman. Writing/Production, Andy Zieminski. Printing, House of Printing, Inc. Printed on paper that is 100 percent post-consumer waste and process chlorine free.

COMMUNITY VITALITY

Thriving communities—rural and urban—are a key to quality of life for all. When farmers and ranchers hire help and sell in nearby communities, for example, they contribute to the local economy. In turn, they have a nearby hub for raising their families and a possible market for their products.

ECOLOGICAL INSECT AND WEED MANAGEMENT

Ecological pest management avoids single-bullet solutions that can harm beneficial insects, and instead uses a combination of many complementary strategies—for example, biological controls such as trap crops for insect pests, physical removal of weeds and insects, application of chemicals if necessary, and other methods such as selecting crops that smother or shade out weeds and creating habitat for beneficial insects.

GRAZING

Management-intensive, or rotational, grazing systems keep animals moving from pasture to pasture to provide high-quality forage and reduce feed costs. An added bonus is that—with a little attention from the farmer or rancher—grazing animals distribute manure across the field, which contributes to soil fertility and reduces the need for purchased fertilizer inputs.

CONSERVATION TILLAGE

Many soil conservation practices—contour tillage, reduced tillage and no-till, to name a few—help prevent soil loss from wind and water erosion. Conservation tillage systems also help minimize soil compaction, conserve water and store carbon to help offset greenhouse gas emissions.

COVER CROPS

Growing plants such as rye, clover or vetch after harvesting a cash crop can provide multiple benefits, including weed and insect suppression, erosion control and improved soil quality. Cover crops are now grown on millions of acres across the country.

CROP, LIVESTOCK AND LANDSCAPE DIVERSITY

Growing a greater variety of crops and livestock—especially genetically diverse open-pollinated plants and heritage breeds—can make a farm more resilient to diseases and pests, as well as extremes in weather and market conditions. Certain agroforestry techniques—inter-planting trees with crops and growing shade-loving specialty crops, for example—help conserve soil and water, provide wildlife habitat and increase beneficial insect populations.

NUTRIENT MANAGEMENT

Well-managed and properly applied on-farm nutrient sources—such as manure and leguminous cover crops—build soil, protect water quality and reduce purchased fertilizer costs.

ON-FARM ENERGY CONSERVATION AND PRODUCTION

Farmers and ranchers are using energy-saving devices, windmills and solar power, while also learning how to grow and process their own fuel. These practices not only make farm operations more profitable, clean and efficient, they help reduce dependence on foreign oil and reduce greenhouse gas emissions.

A WHOLE-FARM APPROACH

A whole-farm approach combines the practices listed above into one integrated management system that works with nature: Reducing tillage and careful application of on-farm nutrient sources, for example, build soil organic matter; energy costs are reduced when fuel is produced from waste or renewable sources; pests are controlled by plant and landscape diversity; income is boosted by more efficient use of on-farm resources—and the list goes on.

WHAT ARE YOUR IDEAS? Read on for some of SARE's cream-of-the-crop stories about successful sustainable agriculture, then consider applying for your own grant... (view all SARE project results at www.sare.org/projects)

Ana Vivar sells a bounty of vegetables at a market in Santa Fe, N.M. The produce is from Santa Cruz Farm, where Don Bustos, Vivar's father, uses ecological pest management, cover crops, on-farm energy production and other sustainable techniques (see p. 5).

Photo courtesy Santa Cruz Farm

Hydroponic Systems

University of Massachusetts Amherst

Hydroponics, in its most basic definition is a production method where the plants are grown in a nutrient solution rather than in soil. Over the past few years, a number of variations to the basic system have been developed. Although it is possible to use hydroponics on outdoor crops, most of the production in the U.S. today is in greenhouses.

The greenhouse and its environment control system are the same whether plants are grown conventionally or with hydroponics. The difference comes from the support system and the method of supplying water and nutrients.

Advantages

- Greater plant density- plants can be moved as they grow. Use of a growth room for germination and seedling production and the spacing of certain crops in the greenhouse decreases the average area needed per plant over conventional soil production.
- Higher yields- Reports of higher yields and better quality are common although equal yields should be able to be obtained from a conventional cropping system.
- Less water consumption- In methods where the root system is contained in a closed trough or tube, less evaporation occurs and water consumption is reduced.

Disadvantages

- Increased initial investment- several dollars per square foot are added by the pumps, tanks, controls and support system. If supplemental lighting or a growth room is included, a large additional cost will be incurred.
- Higher energy costs -pump and lighting operation increase the electricity costs.
- More technical skill is needed -a grower with a good chemical and plant production background is required.

Crops

Although almost any crop can be grown hydroponically, the most common are leaf lettuce, tomatoes, peppers, cucumbers, strawberries, watercress, celery and some herbs. One key factor in system design for a particular crop is how it is supported in the nutrient solution.

Growing systems

Many innovative systems have been developed that replace the traditional gravel filled bed. When evaluating the type of system to install, consideration should be given to such factors as the type of crop grown, space requirements, growing time, support system and economics. These systems can be set up in either a greenhouse or growth room. Some growers use both; the growth room for germination and seedling production and the greenhouse to grow out the crop. The extra heat from the growth room lights may be used to heat the greenhouse.

Sand/stone culture

This technique for growing almost any type of plant consists of a deep bed (18 -24 inches) of sand, pea stone or trap rock placed in a plastic lined trough or bed which slopes to one point to drain off excess nutrient solution. A minimum slope of 2% is recommended for most systems. Seedlings are set directly into this medium and watered several times per day with the nutrient solution.

Troughs and pipes

Open and closed plastic troughs or PVC pipe are commonly used for lettuce, tomatoes and cucumbers. These may contain just the nutrient solution or may be filled peat moss, vermiculite or perlite. Some are mounted on rollers or movable racks for spacing the plants as they grow. Three inch diameter PVC pipes with holes 6 inches on center are being used for leaf lettuce production. A common length is 10 or 12 feet. Carts may be used to move the pipes from the growing area to the packing room.

Trays

Periodically flooded trays are used for growing lettuce. Plants started in 1 to 2 inch diameter growth blocks are manually spaced as the plants grow. Trays are made from molded plastic or waterproof plywood.

Beds

A system consisting of a plastic lined ground bed with nutrient solution pumped in at one end and drained at the other have been researched at Cornell University, Ithaca NY. Lettuce plants are supported in foam polystyrene flats that float on the solution.

Nutrient film technique

This system developed by Dr. Allen Cooper in England uses channels formed out of thin film plastic. The channels are placed on the ground or benches. Nutrients are supplied through plastic tubing to one end of the channel and drained into a below ground reservoir at the other end. Seedlings are usually grown in pots. Poly bags or grow blocks support the plants in the channel.

Bags

A modified hydroponic system that uses polyethylene film bags filled with a peat-vermiculite mix has been developed. The bags are laid end to end and drip tube or soaker hose inserted to supply the nutrients. The bags may be good for several crops before they have to be replaced.

Aeroponics.

This is another modified system in which the plants are supported through a plastic cover into a closed tank. Nutrients are supplied to the roots as a fine mist or fog.

Other components

Besides the plant support system, tanks, pumps and controls are needed. Tanks made of concrete, plastic or fiberglass are common. Submersible pumps designed for chemical solutions should be used as the fertilizer salts will corrode pumps made for use with water. Controls can be as simple as a time clock and manual switches or as complex as a computer that automatically adjusts the chemical content of the nutrient solution.

Photo by David Wees, https://hellohomestead.com/how-to-create-a-diy-hydroponic-system.

https://www.gardenandgreenhouse.net/articles/hydroponics/do-it-yourself-hydroponics

https://www.youtube.com/watch?v=1PVdQ3-7UIs

https://bit.ly/3yYo9M2

https://bit.ly/3nh16JV

https://mollygreen.com/blog/diy-hydroponic-gardening