NATIONAL GEOGRAPHIC
lesson

Can We Feed the Growing Population?

How do the interconnected resources of our agricultural system affect how much food we can produce?

Content Created by

The Concord Consortium

Activity 1: Using the Land | 45 mins

Directions

1. Introduce the concept of land use by looking at global land use history.

Show the **A Tale of Two Planets** image. (Download the image by clicking on the down arrow in the lower right corner of the media carousel window.) These maps illustrate which land areas have been changed by humans over time. Tell students that humans have changed Earth's landscapes greatly over time. Have students study the evidence of change illustrated on the map models. Then ask:

- *Which areas have been changed by humans for the longest period?* (Europe, Central America, the Middle East, India, and eastern Asia have been used intensively for thousands of years, along with some areas along the Andes Mountains in South America, northeastern North America, and parts of sub-Saharan Africa. The orange to red coloration on the map shows this.)
- *How do you think humans changed the land?* (Humans have used the land for farming as well as housing.)

2. Discuss the role of uncertainty in the scientific process.

Tell students that science is a process of learning how the world works and that scientists do not know the “right” answers when they start to investigate a question. Students can see examples of scientists' uncertainty in forecasting crop yields. Show the **Projection of Maize Crop Yields in France** image from the media carousel above. (Download the image by clicking on the down arrow in the lower right corner of the carousel window.) Tell students that the graphs in this image show the projection of maize crop yields in France over this time period—the average daily precipitation, number of hot days, and yield of maize. The gray line shows the predictions for crop yield based on technological improvements. The pink shading shows the expected yield based on temperature and precipitation influences. The red lines outside the pink shading show the total uncertainty. Ask:

- *Does the technology trend (gray line) accurately predict crop yields?* (No, the technology trend does not accurately predict crop yields. This is because crop yields are dependent on temperature and precipitation as well as technological improvements.)

- *Why do you think the crop models still have uncertainty even after accounting for precipitation and temperature differences year to year?* (Student answers will vary. The crop yield could be affected by a pest infestation.)

Tell students they will be asked questions about the certainty of their predictions and that they should think about what scientific data is available as they assess their certainty with their answers. Encourage students to discuss the scientific evidence with each other to better assess their level of certainty with their predictions.

3. Introduce the concept of stocks and flows in a system.

Tell students that materials flow into and out of systems. The flow of the materials over time can change and can be influenced by many different factors and interacting parts.

Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a stock and flow in a system, as described in the scenario below.

There is a bathtub with water flowing in from the faucet and water leaving through the drain. Ask:

- *When the drain is plugged, what happens to the level of water in the bathtub?* (The water level will increase because the outflow of water is stopped, but water keeps coming in from the faucet.)

- *When the faucet is turned off, what happens to the level of water in the bathtub?* (The water level will decrease because the inflow of water is stopped, but the water keeps leaving through the drain.)

- *How can the level of water in the bathtub be kept at the same level?* (The water in the bathtub can be kept at the same level by making the inflow equal to the outflow. Then the water that comes in through the faucet will be offset by the water that leaves through the drain.)

Tell students they will be following the flow of materials, in this case the amount of topsoil and nutrients, through a system. Let students know they will be exploring some environmental and human factors that contribute to changes in the quality of soil in the modeled system.

4. Implement the Using the Land interactive.

Provide students with the link to the Using the Land interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students they will be working through a series of pages of questions related to the data in the interactive. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 1 of the **Can We Feed the Growing Population?** lesson.

5. Discuss the issues.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- *How have humans changed Earth's natural landscape?* (Humans have cut down forests and plowed up prairies for farming and housing. Waterways have been changed for irrigation and to prevent seasonal flooding. Other areas have been less affected by human actions, but there are few places on Earth that have not been affected by human actions.)
- *What is a consequence of turning forested land into farmland or residential land?* (The forests provide homes for many organisms. Many forest lands are sloped, which may not be good for either farming or housing. Forests provide oxygen, prevent water runoff and erosion, and store carbon dioxide.)
- *How has the proportion of agricultural land in the United States changed since 1950?* (Agricultural land has decreased. Urban areas have increased, as have special use areas [parks, wilderness areas, defense/industrial lands]).
- *Why isn't agricultural land spread evenly around the world?* (Agricultural land needs to have good soil, adequate precipitation, and moderate temperature. These features aren't found evenly across Earth.)

Tip

This activity is part of a sequence of activities in the Can We Feed the Growing Population? lesson. The activities work best if used in sequence.

Modification

This activity may be used individually or in groups of two or three students. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Tip
To save your students' data for grading online, register your class for free at the High-Adventure Science portal page.

Informal Assessment
1. Check students' comprehension by asking them the following questions:

- Has agricultural production kept pace with human population growth in areas around the world?
- What are some consequences of turning agricultural land into suburbs or cities?
- What are some consequences of turning forested land into farmland, suburbs, or cities?
- Why isn't all land equally suitable for agricultural uses?

2. Use the answer key to check students' answers on embedded assessments.

Objectives
Subjects & Disciplines
Science
- Earth science
- General science

Learning Objectives
Students will:

- describe some consequences of using land (forests, agricultural land) for other purposes (human development)
- explain why agricultural land is unevenly distributed on Earth's land surfaces
- describe how humans have changed Earth's landscape

Teaching Approach
- Learning-for-use

Teaching Methods
- Discussions
- Multimedia instruction
- Self-paced learning
- Visual instruction
- Writing

Skills Summary
This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Critical Thinking and Problem Solving
- 21st Century Themes
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Evaluating
  - Understanding

National Standards, Principles, and Practices

National Science Education Standards

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard D-1:**
Structure of the earth system
• **(5-8) Standard F-1:**
Personal health
• **(5-8) Standard F-4:**
Risks and benefits
• **(9-12) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(9-12) Standard A-2:**
Understandings about scientific inquiry
• **(9-12) Standard C-5:**
Matter, energy, and organization in living systems
• **(9-12) Standard F-1:**
Personal and community health
• **(9-12) Standard F-2:**
Population growth
• **(9-12) Standard F-4:**
Environmental quality
• **(9-12) Standard F-5:**
Natural and human-induced hazards

Common Core State Standards for English Language Arts & Literacy

• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.9-10.1

• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.6-8.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.6-8.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.6-8.4
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Key Ideas and Details, RST.9-10.3
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Key Ideas and Details, RST.11-12.1
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Key Ideas and Details, RST.11-12.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.11-12.4

ISTE Standards for Students (ISTE Standards*S)

• **Standard 3:**
Research and Information Fluency
• **Standard 4:**
Critical Thinking, Problem Solving, and Decision Making

Next Generation Science Standards

• **Crosscutting Concept 1:**
Patterns
• **Crosscutting Concept 3:**
Scale, proportion, and quantity
• **Crosscutting Concept 7:**
Stability and change
• **Science and Engineering Practice 1:**
Asking questions and defining problems
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 5:**
Using mathematics and computational thinking
• **Science and Engineering Practice 6:**
Constructing explanations and designing solutions
• **Science and Engineering Practice 7:**
Engaging in argument from evidence
• **Science and Engineering Practice 8:**
Obtaining, evaluating, and communicating information

Preparation

Background & Vocabulary

Background Information

Human populations around the world have increased. Agricultural operations around the world produce more than enough food to feed the human population, due in part to chemical and biological innovations.

However, many high-quality farmlands are threatened by development. Housing, retail, and industrial areas have encroached on agricultural land. Other high-quality fields are used to grow food for fuel, rather than food for food (either animal or human). The question of whether the agricultural revolution will continue to produce sufficient amounts of nutritious food and maintain the land and natural environment is still open.

This activity focuses on the land use changes that have occurred in the United States since 1949. Even so, the general information is applicable to any country that has farmland. Will the farmland continue to be productive in the future?

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
agriculture	*noun*	the art and science of cultivating the land for growing crops (farming) or raising livestock (ranching).
biosphere	*noun*	part of the Earth where life exists.
land management	*noun*	process of balancing the interests of development, resources, and sustainability for a region.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
sustainability	*noun*	use of resources in such a manner that they will never be exhausted.

Term	Part of Speech	Definition
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Funder

This material is based upon work supported by the National Science Foundation under Grant No. DRL-1220756. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Partner

Activity 2: Preserving Soils | 45 mins

Directions

1. Spark students' thinking about preserving soils.

Tell students that plants get most of their nutrients through their roots, which grow in soil. Ask:

- *How can the soil be worn away?* (Soil can be eroded by wind and by water.)
- *What do you think can prevent soil erosion?* (Answers will vary. To prevent erosion, you have to protect the soil from wind and water. This can be done by covering it with plants or rocks. Holding the soil together by covering it and preventing flooding events will prevent soil loss.)

2. Discuss the role of uncertainty in the scientific process.

Tell students that science is a process of learning how the world works and that scientists do not know the "right" answers when they start to investigate a question. Students can see examples of scientists' uncertainty in forecasting crop yields. Show the **Projection of Maize Crop Yields in France** image from the media carousel above. (Download the image from the media carousel above by clicking on the down arrow in the lower right corner of the image window.) Tell students that these graphs in this image show the projection of maize crop yields in France over this time period—the average daily precipitation, number of hot days, and yield of maize. The gray line shows the predictions for crop yield based on technological improvements. The pink shading shows the expected yield based on temperature and precipitation influences. The red lines outside the pink shading show the total uncertainty. Ask:

- *Does the technology trend (gray line) accurately predict crop yields?* (No, the technology trend does not adequately predict crop yields. This is because crop yields are dependent on temperature and precipitation as well as technological improvements.)
- *Why do you think the crop models still have uncertainty even after accounting for precipitation and temperature differences year to year?* (Student answers will vary. The crop yield could be affected by a pest infestation.)

Tell students they will be asked questions about the certainty of their predictions and that they should think about what scientific data is available as they assess their certainty with their answers. Encourage students to discuss the scientific evidence with each other to better assess their level of certainty with their predictions.

3. Introduce the concept of stocks and flows in a system.

Tell students that materials flow into and out of systems. The flow of the materials over time can change and can be influenced by many different factors and interacting parts.

Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a stock and flow in a system, as described in the scenario below.

There is a bathtub with water flowing in from the faucet and water leaving through the drain. Ask:

- *When the drain is plugged, what happens to the level of water in the bathtub?* (The water level will increase because the outflow of water is stopped, but water keeps coming in from the faucet.)
- *When the faucet is turned off, what happens to the level of water in the bathtub?* (The water level will decrease because the inflow of water is stopped, but the water keeps leaving through the drain.)
- *How can the level of water in the bathtub be kept at the same level?* (The water in the bathtub can be kept at the same level by making the inflow equal to the outflow. Then the water that comes in through the faucet will be offset by the water that leaves through the drain.)

Tell students they will be following the flow of materials, in this case the amount of topsoil and nutrients, through a system. Let students know they will be exploring some environmental and human factors that contribute to changes in the quality of soil in the modeled system.

4. Introduce and discuss the use of computational models.

Introduce the concept of computational models and give students an example of a computational model they may have seen, such as forecasting the weather. Project the **NOAA Weather Forecast Model**, which provides a good example of a computational model. Tell students that scientists use weather models to predict future conditions based on current information about the energy and moisture in the atmosphere. There are many different types of models. Scientists can use soil models to predict the movement and quality of soil in a region. Let students know that they will be using models of soil movement and quality.

5. Have students launch the Preserving Soils interactive.

Provide students with the link to the Preserving Soils interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students they will be working through a series of pages of questions related to the data in the interactive. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 2 of the **Can We Feed the Growing Population?** lesson.

6. Discuss the issues.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- *Why do plants' roots grow extensively in the topsoil?* (The topsoil has the most nutrients. Plants get nutrients through their roots. The topsoil is the best place to get the nutrients.)
- *How did you use the model (***Model 2: Landscapes With Plants***) to prevent erosion on a hillside?* (Plants reduced the erosion rate on the slope. This is because the plants' roots hold the topsoil together, preventing it from eroding.)
- *How does erosion affect plant growth?* (Erosion will cause plants to not grow as well. If the soil erodes, the nutrients go with it. If the soil doesn't have enough nutrients, the plants won't grow well. If the plants won't grow well, then more soil will erode because there are few roots to hold the soil together.)

Tip

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Tip

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Modification

This activity may be used individually or in groups of two or three students. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

1. Check students' comprehension by asking them the following questions:

- What natural processes can result in soil erosion?
- What natural process can prevent or minimize soil erosion?
- Is erosion more likely on a slope or on a flat area? Why?
- How does erosion affect plant growth?

2. Use the answer key to check students' answers on embedded assessments.

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- describe how plants prevent or minimize erosion
- describe the relationship between slope and erosion rates
- describe the characteristics of topsoil (soil layer from which plants derive nutrients)
- describe why a plant's growth could be affected by erosion

Teaching Approach

- Learning-for-use

Teaching Methods

- Discussions
- Multimedia instruction
- Self-paced learning
- Visual instruction
- Writing

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Critical Thinking and Problem Solving
- 21st Century Themes
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Evaluating
  - Understanding

National Standards, Principles, and Practices

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• **(5-8) Standard D-1:**
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• **(5-8) Standard F-1:**
Personal health
• **(5-8) Standard F-4:**
Risks and benefits
• **(9-12) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(9-12) Standard A-2:**
Understandings about scientific inquiry
• **(9-12) Standard C-5:**
Matter, energy, and organization in living systems
• **(9-12) Standard F-1:**
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• **(9-12) Standard F-2:**
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• **Standard 3:**
Research and Information Fluency
• **Standard 4:**
Critical Thinking, Problem Solving, and Decision Making

Next Generation Science Standards

• **Crosscutting Concept 1:**
Patterns
• **Crosscutting Concept 2:**
Cause and effect: Mechanism and prediction
• **Crosscutting Concept 3:**
Scale, proportion, and quantity
• **Crosscutting Concept 4:**
Systems and system models
• **Crosscutting Concept 5:**
Energy and matter: Flows, cycles, and conservation
• **Crosscutting Concept 7:**
Stability and change
• **Science and Engineering Practice 1:**
Asking questions and defining problems
• **Science and Engineering Practice 2:**

Developing and using models
• **Science and Engineering Practice 3**:
Planning and carrying out investigations
• **Science and Engineering Practice 4**:
Analyzing and interpreting data
• **Science and Engineering Practice 5**:
Using mathematics and computational thinking
• **Science and Engineering Practice 6**:
Constructing explanations and designing solutions
• **Science and Engineering Practice 7**:
Engaging in argument from evidence
• **Science and Engineering Practice 8**:
Obtaining, evaluating, and communicating information

Preparation

Background & Vocabulary

Background Information

Agricultural land is productive because of its fertile soils. It takes many years to make a fertile soil. Soil is made as rocks are weathered into smaller particles. The mineral content of a soil is related to the rocks that were broken down to form it. As the rocks start to break down, plants' roots can take hold in the cracks and further break down the rocks.

Additionally, as the plants die and decay, they add organic matter to the soil. A high-quality soil has a large amount of organic matter, which is found mainly in the topsoil (the top 12 inches of soil). Plants' roots obtain nutrients from the topsoil. The topsoil is very high in organic matter, water, and nutrients.

Topsoil can be quickly eroded through the actions of wind and water. If the soil is not held together, it can literally blow away on the wind, as happened in large areas of the U.S. Midwest during the Dust Bowl era. Similarly, loose soil can be washed away by flooding events.

Good land management practices can prevent or minimize the amount of erosion from a parcel of land. Part of a good land management practice involves making sure the soil is always held together. One way to do this is to keep the land continually planted; the plants' roots will hold the soil together and prevent it from blowing or washing away.

Prior Knowledge

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Recommended Prior Activities

- Using the Land

Vocabulary

Term	Part of Speech	Definition
arable	*adjective*	land able to produce crops.
erosion	*noun*	act in which earth is worn away, often by water, wind, or ice.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
organic	*adjective*	composed of living or once-living material.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.
terrain	*noun*	topographic features of an area.
topsoil	*noun*	the most valuable, upper layer of soil, where most nutrients are found.

Funder

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Partner

Activity 3: Climate and Crop Growth | 45 mins

Directions

1. Engage students in learning about climate and crop growth.

Tell students that plants need water and sunlight to grow. Some plants have long growing seasons while others have shorter growing seasons. Show the **Climate Graphs** image. (Download the image from the media carousel above by clicking on the down arrow in the lower right corner of the carousel window.) These graphs provide climate information for Quibdó, Colombia; Minneapolis, Minnesota; and El Paso, Texas. Ask:

- *Will a crop grow the same in Quibdó, Colombia and Minneapolis, Minnesota?* (No, the crops will grow differently. There is no dry season in Quibdó, and the temperature remains warm year-round. The climate in Minneapolis is very different.)
- *Would you plant a crop that needs a lot of moisture in El Paso, Texas?* (No, a crop that requires a lot of moisture would not do well in El Paso unless there was irrigation. El Paso has a very dry climate.)

2. Discuss the role of uncertainty in the scientific process.

Tell students that science is a process of learning how the world works and that scientists do not know the “right” answers when they start to investigate a question. Tell students that they can see examples of scientists' uncertainty in forecasting crop yields. Show the **Projection of Maize Crop Yields in France** graphs. (Download the image by clicking on the down arrow in the lower right corner of the carousel window.) Tell students that these graphs show the average daily precipitation, number of hot days, and yield of maize. The gray line shows the predictions for crop yield based on technological improvements. The pink shading shows the expected yield based on temperature and precipitation influences. The total uncertainty is shown by the red lines outside the pink shading. Ask:

- *Does the technology trend (gray line) accurately predict crop yields?* (No, the technology trend does not adequately predict crop yields. This is because crop yields are dependent on temperature and precipitation as well as technological improvements.)
- *Why do you think the crop models still have uncertainty even after accounting for precipitation and temperature differences year to year?* (Student answers will vary. The crop yield could be affected by a pest infestation.)

Tell students they will be asked questions about the certainty of their predictions. Let students know that they should think about what scientific data is available as they assess their certainty with their answers. Encourage them to discuss the scientific evidence with each other to better assess their level of certainty with their predictions.

3. Introduce the concept of stocks and flows in a system.

Tell students that materials flow into and out of systems. The flow of the materials over time can change and can be influenced by many different factors and interacting parts.

Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a stock and flow in a system, as described in the scenario below.

There is a bathtub with water flowing in from the faucet and water leaving through the drain. Ask:

- *When the drain is plugged, what happens to the level of water in the bathtub?* (The water level will increase because the outflow of water is stopped, but water keeps coming in from the faucet.)
- *When the faucet is turned off, what happens to the level of water in the bathtub?* (The water level will decrease because the inflow of water is stopped, but the water keeps leaving through the drain.)
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Tell students they will be following the flow of materials, in this case the amount of topsoil and nutrients, through a system. Let students know they will be exploring some environmental and human factors that contribute to changes in the quality of soil in the modeled system.

4. Introduce and discuss the use of computational models.

Introduce the concept of computational models and give students an example of a computational model they may have seen, such as forecasting the weather. Project the **NOAA Weather Forecast Model**, which provides a good example of a computational model. Tell students that scientists use weather models to predict future conditions based on current information about the energy and moisture in the atmosphere. There are many different types of models. Scientists can use soil models to predict the movement and quality of soil in a region. Let students know that they will be using models of soil movement and quality.

5. Have students launch the Climate and Crop Growth interactive.

Provide students with the link to the Climate and Crop Growth interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students they will be working through a series of pages of questions related to the data in the interactive. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 3 of the **Can We Feed the Growing Population?** lesson.

6. Discuss the issues.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- *What happens in the model (***Model 3: Landscapes with Climate Controls***) when there is very little precipitation?* (The plants don't grow as well as they did when there was more precipitation.)

- *If you know the climate of an area, can you predict its ability to grow crops?* (If you know the climate of an area, you can start to predict its ability to grow crops, but you cannot accurately predict its ability to grow crops. This is because climate is only one part of growing crops. You also need to have good soil to grow crops. If the climate is suitable, it doesn't mean the soil is suitable.)

- *What can farmers do to grow crops even when the weather isn't cooperative?* (Farmers can irrigate their fields during dry weather. During wet weather, they can try to drain their fields more quickly so the plants don't drown.)

Tip

If you would like to save student data for grading online, register your class for free at the High-Adventure Science portal page.

Tip

This activity is part of a sequence of activities in the Can We Feed the Growing Population? lesson. The activities work best if used in sequence.

Modification

This activity may be used individually or in groups of two or three students. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

1. Check students' comprehension by asking them the following questions:

- What happens to plant growth if there is not enough precipitation?
- What happens to plant growth if there is too much precipitation?
- What climates are common among agriculturally suitable lands around the world?

2. Use the answer key to check students' answers on embedded assessments

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- describe the role of precipitation in plant growth
- describe the role of temperature in plant growth

Teaching Approach

- Learning-for-use

Teaching Methods

- Discussions
- Multimedia instruction
- Self-paced learning
- Visual instruction
- Writing

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Critical Thinking and Problem Solving
- 21st Century Themes
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Evaluating
  - Understanding

National Standards, Principles, and Practices

National Science Education Standards

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard D-1:**

Structure of the earth system
• **<u>(5-8) Standard F-1</u>:**
Personal health
• **<u>(5-8) Standard F-4</u>:**
Risks and benefits
• **<u>(9-12) Standard A-1</u>:**
Abilities necessary to do scientific inquiry
• **<u>(9-12) Standard A-2</u>:**
Understandings about scientific inquiry
• **<u>(9-12) Standard C-5</u>:**
Matter, energy, and organization in living systems
• **<u>(9-12) Standard F-1</u>:**
Personal and community health
• **<u>(9-12) Standard F-2</u>:**
Population growth
• **<u>(9-12) Standard F-4</u>:**
Environmental quality
• **<u>(9-12) Standard F-5</u>:**
Natural and human-induced hazards

Common Core State Standards for English Language Arts & Literacy

• **<u>Reading Standards for Literacy in Science and Technical Subjects 6-12</u>:**
Key Ideas and Details, RST.6-8.3
• **<u>Reading Standards for Literacy in Science and Technical Subjects 6-12</u>:**
Key Ideas and Details, RST.11-12.3
• **<u>Reading Standards for Literacy in Science and Technical Subjects 6-12</u>:**
Key Ideas and Details, RST.11-12.1
• **<u>Reading Standards for Literacy in Science and Technical Subjects 6-12</u>:**
Craft and Structure, RST.9-10.4
• **<u>Reading Standards for Literacy in Science and Technical Subjects 6-12</u>:**
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Key Ideas and Details, RST.6-8.1
• **<u>Reading Standards for Literacy in Science and Technical Subjects 6-12</u>:**
Craft and Structure, RST.11-12.4

ISTE Standards for Students (ISTE Standards*S)

• **<u>Standard 3</u>:**
Research and Information Fluency

• **Standard 4**:
Critical Thinking, Problem Solving, and Decision Making

Next Generation Science Standards

• **Crosscutting Concept 1**:
Patterns
• **Crosscutting Concept 2**:
Cause and effect: Mechanism and prediction
• **Crosscutting Concept 3**:
Scale, proportion, and quantity
• **Crosscutting Concept 4**:
Systems and system models
• **Crosscutting Concept 5**:
Energy and matter: Flows, cycles, and conservation
• **Crosscutting Concept 7**:
Stability and change
• **Science and Engineering Practice 1**:
Asking questions and defining problems
• **Science and Engineering Practice 2**:
Developing and using models
• **Science and Engineering Practice 3**:
Planning and carrying out investigations
• **Science and Engineering Practice 4**:
Analyzing and interpreting data
• **Science and Engineering Practice 5**:
Using mathematics and computational thinking
• **Science and Engineering Practice 6**:
Constructing explanations and designing solutions
• **Science and Engineering Practice 7**:
Engaging in argument from evidence
• **Science and Engineering Practice 8**:
Obtaining, evaluating, and communicating information

Preparation

Background & Vocabulary

Background Information

An area's climate affects the types of plants that can grow there. Plant growth is dependent on precipitation and temperature. If the precipitation level is too high or too low or if the temperature is too high or too low, plants may not grow well.

Some climates are better for growing crops than others. Agriculturally suitable lands have adequate precipitation and moderate temperatures as well as good soils. Farmers regularly have to contend with wet and dry events to grow crops, even in hospitable climates.

Prior Knowledge

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Recommended Prior Activities

- Preserving Soils
- Using the Land

Vocabulary

Term	Part of Speech	Definition
agriculture	*noun*	the art and science of cultivating the land for growing crops (farming) or raising livestock (ranching).
biosphere	*noun*	part of the Earth where life exists.
climate	*noun*	all weather conditions for a given location over a period of time.
drought	*noun*	period of greatly reduced precipitation.
landscape	*noun*	the geographic features of a region.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
soil	*noun*	top layer of the Earth's surface where plants can grow.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Funder

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Partner

The Concord Consortium

Activity 4: Soil Quality | 45 mins

Directions

1. Engage students in learning about soils and crop growth.

Tell students that plants grow better in high-quality soils than in lower-quality soils. Ask:

- *Soil quality is a measure of the level of nutrients in soil and its structure. How does plant growth reflect the soil quality?* (Plants grow better in high-quality soil because there are more nutrients in it. They grow less well in lower-quality soils because there are not sufficient nutrients.)
- *How do you think humans could improve the quality of soils?* (Answers will vary. Soil quality can be improved by adding more nutrients, which can be done by composting or leaving more roots in the soil year to year.)

2. Discuss the role of uncertainty in the scientific process.

Tell students that science is a process of learning how the world works and that scientists do not know the "right" answers when they start to investigate a question. Let students know they can see examples of scientists' uncertainty in forecasting crop yields. Show the **Projection of Maize Crop Yields in France** graphs. (Download the image from the media carousel above by clicking on the down arrow in the lower right corner of the carousel window.) Tell students these graphs show the average daily precipitation, number of hot days, and yield of maize. The gray line shows the predictions for crop yield based on technological improvements. The pink shading shows the expected yield based on temperature and precipitation influences. The total uncertainty is shown by the red lines outside the pink shading. Ask:

- *Does the technology trend (gray line) accurately predict crop yields?* (No, the technology trend does not adequately predict crop yields. This is because crop yields are dependent on temperature and precipitation as well as technological improvements.)
- *Why do you think the crop models still have uncertainty even after accounting for precipitation and temperature differences year to year?* (Student answers will vary. The crop yield could be affected by a pest infestation.)

Tell students that they will be asked questions about the certainty of their predictions. Let students know that they should think about what scientific data is available as they assess their certainty with their answers. Encourage them to discuss the scientific evidence with each other to better assess their level of certainty with their predictions.

3. Introduce the concept of stocks and flows in a system.

Tell students that materials flow into and out of systems. The flow of the materials over time can change and can be influenced by many different factors and interacting parts.

Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a stock and flow in a system, as described in the scenario below.

There is a bathtub with water flowing in from the faucet and water leaving through the drain. Ask:

- *When the drain is plugged, what happens to the level of water in the bathtub?* (The water level will increase because the outflow of water is stopped, but water keeps coming in from the faucet.)
- *When the faucet is turned off, what happens to the level of water in the bathtub?* (The water level will decrease because the inflow of water is stopped, but the water keeps leaving through the drain.)
- *How can the level of water in the bathtub be kept at the same level?* (The water in the bathtub can be kept at the same level by making the inflow equal to the outflow. Then the water that comes in through the faucet will be offset by the water that leaves through the drain.)

Tell students they will be following the flow of materials, in this case the amount of topsoil and nutrients, through a system. Let students know they will be exploring some environmental and human factors that contribute to changes in the quality of soil in the modeled system.

4. Introduce and discuss the use of computational models.

Introduce the concept of computational models and give students an example of a computational model they may have seen, such as forecasting the weather. Project the **NOAA Weather Forecast Model**, which provides a good example of a computational model. Tell students that scientists use weather models to predict future conditions based on current information about the energy and moisture in the atmosphere. There are many different types of models. Scientists can use soil models to predict the movement and quality of soil in a region. Let students know that they will be using models of soil movement and quality.

5. Have students launch the Soil Quality interactive.

Provide students with the link to the Soil Quality interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students they will be working through a series of pages of questions related to the data in the interactive. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 4 of the **Can We Feed the Growing Population?** lesson.

6. Discuss the issues.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- *In **Model 5: Landscape With Soil Quality Measurements**, how could you treat the soil to improve its quality?* (You can minimally till the soil, leaving roots in the soil year to year. This increases the soil quality.)
- *How does constantly tilling the soil decrease its quality?* (Lots of tillage breaks up the plant roots. This allows the soil to erode. When the soil erodes, it loses nutrients. That decreases the quality of the soil.)

Why does crop rotation work? (Different plants have different nutrient requirements. If you plant the same type of plant in a field year after year, the nutrients that it requires will be depleted from the soil. If you rotate other crops in, you have diversity in their nutrient requirements. Some plants add nutrients to the soil as they grow; legumes add nitrogen to the soil, for example. Using different crops to fertilize each other leads to less need for inorganic fertilizers.)

Tip

If you would like to save student data for grading online, register your class for free at the High-Adventure Science portal page.

Tip

This activity is part of a sequence of activities in the Can We Feed the Growing Population? lesson. The activities work best if used in sequence.

Modification

This activity may be used individually or in groups of two or three students. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

1. Check students' comprehension by asking them the following questions:

- Why do plants grow better in high-quality soils than in low-quality soils?
- What type of tillage (intensive or conservative) results in better-quality soils? Why?
- How can plants increase soil quality?
- Why does crop rotation increase soil quality?
- What happens to plant growth if there are not enough nutrients in the soil?
- What are the consequences of adding too much fertilizer to plants?

2. Use the answer key to check students' answers on embedded assessments.

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- describe the role of nutrients in plant growth
- describe how crop rotation can minimize the amount of fertilizer that needs to be added to the field
- describe a farming practice that can increase soil quality and decrease erosion

Teaching Approach

- Learning-for-use

Teaching Methods

- Discussions
- Multimedia instruction
- Self-paced learning
- Visual instruction
- Writing

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
    - Information, Media, and Technology Skills
        - Information, Communications, and Technology Literacy
    - Learning and Innovation Skills
        - Critical Thinking and Problem Solving
- 21st Century Themes
    - Global Awareness

- Critical Thinking Skills
    - Analyzing
    - Evaluating
    - Understanding

National Standards, Principles, and Practices

National Science Education Standards

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard F-1:**
Personal health
• **(5-8) Standard F-4:**
Risks and benefits
• **(9-12) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(9-12) Standard A-2:**
Understandings about scientific inquiry
• **(9-12) Standard C-5:**
Matter, energy, and organization in living systems
• **(9-12) Standard F-1:**
Personal and community health
• **(9-12) Standard F-2:**
Population growth
• **(9-12) Standard F-4:**
Environmental quality
• **(9-12) Standard F-5:**
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Key Ideas and Details, RST.6-8.1
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• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.9-10.4

ISTE Standards for Students (ISTE Standards*S)

• **Standard 3:**
Research and Information Fluency
• **Standard 4:**
Critical Thinking, Problem Solving, and Decision Making

Next Generation Science Standards

• **Crosscutting Concept 1:**
Patterns
• **Crosscutting Concept 2:**
Cause and effect: Mechanism and prediction
• **Crosscutting Concept 3:**
Scale, proportion, and quantity
• **Crosscutting Concept 4:**
Systems and system models
• **Crosscutting Concept 5:**
Energy and matter: Flows, cycles, and conservation
• **Crosscutting Concept 7:**
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• **Science and Engineering Practice 1:**
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• **Science and Engineering Practice 4:**
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• **Science and Engineering Practice 5:**
Using mathematics and computational thinking
• **Science and Engineering Practice 6:**
Constructing explanations and designing solutions
• **Science and Engineering Practice 7:**
Engaging in argument from evidence
• **Science and Engineering Practice 8:**
Obtaining, evaluating, and communicating information

Preparation

Background & Vocabulary

Background Information

Plant growth is affected by the amount of nutrients and moisture in the soil. High-quality soils contain a lot of organic matter, nutrients, and water. Soil quality is affected by farming practices.

Plowing and tilling can disrupt soil structure as the soil is turned over for planting. Two methods of tilling are compared in this activity: intensive tillage and conservative tillage. In intensive tillage, the soil structure is disturbed as it is completely turned over and thoroughly mixed. In conservative tillage, the soil is minimally disturbed during planting, cultivating, and harvesting. Conservative tillage leaves more plant roots in the soil, leading to more organic material in the soil and less erosion because the soil is better held together against the actions of wind and water.

Soil quality can be increased by returning organic matter to the soil. Composting is one way to return organic material to the soil. On a large scale, farmers can leave plant material in the field after harvest so that it can decompose and return nutrients to the soil, as is done in conservative tillage strategies.

The nutrients in soil can come from the decomposition of organic material, or inorganic fertilizers can be added to provide the nutrients that plants need. The nutrients commonly provided by fertilizer are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen promotes the growth of leaves and vegetation. Phosphorus promotes root and shoot (stem) growth. Potassium regulates the water and nutrient movement in plant cells, promoting flowering and fruiting in plants.

There are consequences to adding too much fertilizer to plants. Adding fertilizers at the wrong time (such as when the plant is not growing) can lead to “fertilizer burn” as the plants lose water; fertilizers are salts. Adding too much fertilizer can result in runoff into nearby waterways in a heavy rain event. The nutrient-rich water can cause algal blooms in relatively nutrient-poor waterways far from the fertilizer application. (This is because algal growth in the waterways is generally nutrient-limited; the fertilizer adds the nutrient that was limited, leading to massive growth spurts.) As the algae die off and decompose, the oxygen content of the water drops, leading to large fish kills because the fish are no longer able to get enough oxygen to survive.

Different plants need different amounts of nutrients. Some types of plants, called legumes (which include peas, beans, soybeans, peanuts, alfalfa, and clover), have nodules on their roots.

Nitrogen-fixing bacteria live in these nodules, producing nitrogen fertilizer as the plants grow. Thus, the legumes fertilize the soil with nitrogen as they grow. There is no need to add nitrogen to these crops because they produce their own.

Even though other types of plants do not produce nutrients as they grow, they still have different nutrient requirements. Alternating the types of plants that are planted in a field each year (crop rotation) allows a previous season's plants to provide nutrients for the next season's plants.

Prior Knowledge

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Recommended Prior Activities

- Climate and Crop Growth
- Preserving Soils
- Using the Land

Vocabulary

Term	Part of Speech	Definition
crop rotation	*noun*	the system of changing the type of crop in a field over time, mainly to preserve the productivity of the soil.
fertilizer	*noun*	nutrient-rich chemical substance (natural or manmade) applied to soil to encourage plant growth.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Funder

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Partner

The Concord Consortium

Activity 5: Best Practices | 45 mins

Directions

1. Engage students' interest in learning about agricultural production.

Show the **Yields of Cereal Grains from 1961 to 2012** graph image. (Download the image from the media carousel above by clicking on the down arrow in the lower right corner of the carousel window.) Tell students that agricultural yields have increased over the past 50 years. Ask:

- *Which area has the highest agricultural production of cereal grains?* (North America has the highest yields of cereal grains.)
- *Why do you think there are occasional dips in crop yields?* (Answers will vary. Yields could drop because the weather was not cooperative or because there were pest infestations.)

Tell students they will explore the factors that led to increased crop yields and be asked to predict whether these increases can continue in the future.

2. Discuss the role of uncertainty in the scientific process.

Tell students that science is a process of learning how the world works and that scientists do not know the "right" answers when they start to investigate a question. Tell students that they can see examples of scientists' uncertainty in forecasting crop yields. Show the **Projection of Maize Crop Yields in France** graphs. (Download the image by clicking on the down arrow in the lower right corner of the media carousel window.) Tell students that these graphs show the average daily precipitation, number of hot days, and yield of maize. The gray line shows the predictions for crop yield based on technological improvements. The pink shading shows the expected yield based on temperature and precipitation influences. The red lines outside the pink shading show the total uncertainty. Ask:

- *Does the technology trend (gray line) accurately predict crop yields?* (No, the technology trend does not adequately predict crop yields. This is because crop yields are dependent on temperature and precipitation as well as technological improvements.)
- *Why do you think the crop models still have uncertainty even after accounting for precipitation and temperature differences year to year?* (Student answers will vary. The crop yield could be affected by a pest infestation.)

Tell students they will be asked questions about the certainty of their predictions. Let students know that they should think about what scientific data is available as they assess their certainty with their answers. Encourage them to discuss the scientific evidence with each other to better assess their level of certainty with their predictions.

3. Introduce the concept of stocks and flows in a system.

Tell students that materials flow into and out of systems. The flow of the materials over time can change and can be influenced by many different factors and interacting parts.

Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a stock and flow in a system, as described in the scenario below.

There is a bathtub with water flowing in from the faucet and water leaving through the drain. Ask:

- *When the drain is plugged, what happens to the level of water in the bathtub?* (The water level will increase because the outflow of water is stopped, but water keeps coming in from the faucet.)
- *When the faucet is turned off, what happens to the level of water in the bathtub?* (The water level will decrease because the inflow of water is stopped, but the water keeps leaving through the drain.)
- *How can the level of water in the bathtub be kept at the same level?* (The water in the bathtub can be kept at the same level by making the inflow equal to the outflow. Then the water that comes in through the faucet will be offset by the water that leaves through the drain.)

Tell students they will be following the flow of materials, in this case the amount of topsoil and nutrients, through a system. Let students know they will be exploring some environmental and human factors that contribute to changes in the quality of soil in the modeled system.

4. Have students launch the Best Practices interactive.

Provide students with the link to the Best Practices interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students they will be working through a series of pages of questions related to the data in the interactive. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students this is Activity 5 of the **Can We Feed the Growing Population?** lesson.

5. Discuss the issues.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- *What techniques have been used to increase crop yields around the world?* (Different ways of planting crops have increased the yield of rice, as in the System of Rice Intensification project. Scientists have been able to crossbreed crops to create better-yielding crops, and genetic modifications have allowed some crops to be grown without using pesticides. Scientists have developed fertilizers that can help crops grow to their full potential. Farmers use irrigation during dry years to provide enough moisture to their crops.)

- *What is the relationship between monocropping and pesticide usage?* (When crops are monocropped [a single crop being grown year after year in the same fields] pesticide usage can be high. This is because the pests have a lot of access to a single crop. When the crops are rotated or smaller fields are planted with different crops, the amount of food available to a specific pest is limited. With large fields of the same crop, pests have a feast. To limit the damage caused by pests, pesticides might need to be applied more than they would be in smaller fields with different types of crops.)

- *Do you think agricultural production will continue to increase?* (Answers will vary. There are many challenges facing agriculture today. Much of the increased yield is due to modern technology, but there may be limits to how much technology can continue to increase crop yields. The technology used in North America might not be applicable to agricultural areas of other regions of the world.)

- *Why won't a land management plan from one field be just as good for another field?* (Land management plans should differ for different fields because they should be suited to the land, not a one-size-fits-all solution. A field on a hill will need to be planted differently than a flat field. Fields in a very rainy or windy climate will need to be treated differently than fields in drier, less windy climates. The land management plan should focus on preserving the soil and increasing its quality. This means the first focus should be on preventing erosion. The next focus should be on putting more organic material into the soil so it can hold more moisture and be more nutrient-rich. This can be done with different tillage strategies and crop rotation.)

Tip

If you would like to save student data for grading online, register your class for free at the High-Adventure Science portal page.

Tip

This activity is part of a sequence of activities in the Can We Feed the Growing Population? lesson. The activities work best if used in sequence.

Modification

This activity may be used individually or in groups of two or three students. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

1. Check students' comprehension by asking them the following questions:

- How does monocropping lead to increased fertilizer and pesticide usage?
- Compare and contrast different methods of pest control.

2. Use the answer key to check students' answers on embedded assessments.

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- describe how genetic modifications can increase crop yields
- describe how monocropping can lead to increased fertilizer and pesticide use
- explain why different landscapes require different land management plans
- propose a land management strategy for a field, given information on the topography of the field and climate of the area

Teaching Approach

- Learning-for-use

Teaching Methods

- Discussions
- Multimedia instruction
- Self-paced learning
- Visual instruction
- Writing

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy

        - Learning and Innovation Skills
            - Critical Thinking and Problem Solving
- 21st Century Themes
    - Global Awareness
- Critical Thinking Skills
    - Analyzing
    - Evaluating
    - Understanding

National Standards, Principles, and Practices

National Science Education Standards

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard D-1:**
Structure of the earth system
• **(5-8) Standard F-1:**
Personal health
• **(5-8) Standard F-4:**
Risks and benefits
• **(9-12) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(9-12) Standard A-2:**
Understandings about scientific inquiry
• **(9-12) Standard C-5:**
Matter, energy, and organization in living systems
• **(9-12) Standard F-1:**
Personal and community health
• **(9-12) Standard F-2:**
Population growth
• **(9-12) Standard F-4:**
Environmental quality
• **(9-12) Standard F-5:**
Natural and human-induced hazards

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• **Science and Engineering Practice 6:**
Constructing explanations and designing solutions
• **Science and Engineering Practice 7:**
Engaging in argument from evidence
• **Science and Engineering Practice 8:**
Obtaining, evaluating, and communicating information

Preparation

Background & Vocabulary

Background Information

Agricultural productivity has increased greatly over the past 50 years with more mechanization and specialization of crops. Biological innovations in pest control, such as genetic engineering, have allowed farmers to use fewer pesticides. Biological innovations have also led to more nutritious foods. Scientific studies have resulted in increased yields. It is still a question as to whether these innovations can continue to produce sufficient food from a decreased area of agricultural land.

Prior Knowledge

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Recommended Prior Activities

- Climate and Crop Growth
- Preserving Soils
- Soil Quality
- Using the Land

Vocabulary

Term	Part of Speech	Definition
crop rotation	*noun*	the system of changing the type of crop in a field over time, mainly to preserve the productivity of the soil.
fertilizer	*noun*	nutrient-rich chemical substance (natural or manmade) applied to soil to encourage plant growth.
genetic modification	*noun*	process of altering the genes of an organism.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Made Possible in Part By

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Partner

Partner

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