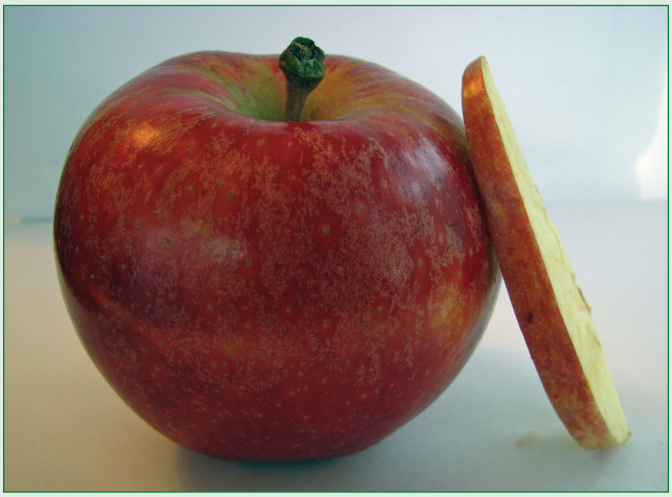
Lesson 5 | Explain-Elaborate

Plant Nutrients and the Environment

At a Glance



Overview

An apple is used to model Earth. Students learn that just $^{1}/_{32}$ of its surface or $^{1}/_{8}$ of the land surface is devoted to farmland. Students use estimates of population growth and land use to calculate how much additional farmland will be needed in the future. They discuss what sacrifices may be needed to feed a larger population. Students investigate the advantages and disadvantages of using organic and commercial fertilizers. Nutrient pollution is defined, and students discuss ways of limiting it.

Major Concepts

- A large portion of Earth's surface is used to grow food.
- The world population is growing at a steady rate.
- Unless food productivity increases, more land will have to be farmed.
- Supplemental plant nutrients help increase food productivity.
- These plant nutrients can be commercial fertilizers and or recycled organic wastes such as animal manures, composts, and human sewage sludge or bio-solids. Fertilizers can be commercial or organic.
- Excesses and deficiencies in plant nutrients can have negative impacts on water, soil, and air.

Objectives

After completing this lesson, students will be able to

- recognize that farmland is a finite resource,
- appreciate that the world's growing population demands an increase in food productivity,
- describe the role plant nutrients plays in increasing food productivity,
- distinguish between organic and commercial fertilizers,
- describe how excess nutrients are harmful to the environment, and
- identify different sources of nutrient pollution.

Teacher Background

Consult the following sections in *Teacher Background:*

7.0 Nourishing Plants with Supplemental Plant Nutrients

8.0 Plant Nutrients and the Environment

9.0 Technology and the Future of Agriculture

In Advance

Photocopies

Activity 1	No photocopies or transparencies
Activity 2	Master 5.1, *Newspaper Articles* (Prepare an overhead transparency.) Master 5.2, *Population and Land Use Graphs* (Make 1 copy for each group of 3 students.) Master 5.3, *Needs of the Future* (Make 1 copy for each group of 3 students.).
Activity 3	Master 5.4, *Thinking about Plant Nutrients* (Make 1 copy for each group of 3 students.*) Master 5.5, *Pros and Cons of Different Fertilizers* (Make 1 copy for each group of 3 students.) Master 5.6, *Nutrient Pollution* (Make 1 copy for each group of 3 students.*) Master 5.7, *Nutrient Pollution Discussion Questions* (Make 1 copy for each group of 3 students.*) *Half of the groups receive Masters 5.4, *Thinking about Plant Nutrients* and 5.5 *Pros and Cons of Different Fertilizers*, and the other half receive Masters 5.6, *Nutrient Pollution* and 5.7, *Nutrient Pollution Discussion Questions*

Materials

Activity 1	For the class: 1 apple 1 knife
Activity 2	No materials except photocopies and transparencies
Activity 2	No materials except photocopies

Preparation

Have an apple and a knife on hand. Prepare photocopies and transparencies.

Procedure

Activity 1: The Big Apple

Tip from the field test

This activity uses an apple as a model of Earth. Students discuss the various ways people use land and make predictions about what percentage of Earth's land is needed to grow our food. After discussing the ways in which land is used (Step 2), you may consider having the students create their own pie charts where they predict the percentages associated with different land uses, especially farming. Later, their predictions can be compared with the actual values revealed by the apple demonstration.

1. **Explain to the class that this activity is concerned with how we as a society use land. The amount of land on Earth stays the same, so as the world's population gets larger, it becomes even more important that we make wise decisions about how it is used.**

Expectations:

Students will:

- assess, on the basis of research, the impact of a factor related to human activity (*e.g., urban sprawl, introduction of invasive species, overhunting/overfishing*) that threatens the sustainability of a terrestrial or aquatic ecosystem.
- analyse some of the risks and benefits of human intervention (*e.g., tree plantations; monoculture of livestock or agricultural crops; overharvesting of wild plants for medicinal purposes; using pesticides to control pests; suppression of wild fires*) to the biodiversity of aquatic or terrestrial ecosystems.
- explain agricultural techniques and forestry practices that aim to maintain both biodiversity and long-term productivity (*e.g., growing a variety of species, inter-planting crops, planting native and heritage varietals instead of hybrids or transgenic species, saving seeds, maintaining some older trees and snags for animal habitat*).
- identify the basic components of soil, water, and air, and describe some of the effects of human activity on soil, water, and air quality.

2. **Explain that land is used for many different reasons. Ask, "What are some of the most important uses for land?" Write students' responses on the board or an overhead transparency.**

   Students' responses may include the following:

   - Farming.
   - Homes.
   - Industries or places where we work.
   - Pastures or land for livestock.
   - Parks, sports, and recreation.
   - Mining.
   - Wildlife habitat (mountain ranges, jungles, deserts, beaches, and tundra).

   If one of these uses is not mentioned by a student, ask guiding questions to bring it out. A student may point out that some land such as a desert has no use. Of course, any land that is not being used by humans can be considered a habitat for wildlife and provides a variety of other economic services for people. For example, wetlands help remove nutrient pollution from rivers, lakes, and estuaries.

3. **Call attention to the apple and the knife. Explain that the apple represents Earth. Ask, "How much of Earth's surface do you think is devoted to farming?"**

   Students' responses will vary. Some may remember that about 70 percent of the surface is water.

4. **Use the knife to cut the apple into 4 equal parts. Set 3 parts aside and hold up 1 part. Explain that the surface of the world is about 70 percent water, so this 1 piece represents that part of the surface that is land.**

   Remind students of the many different uses for this relatively small amount of land.

5. **Use the knife to cut the ¼ piece of apple in half 3 more times, each time discarding ½. Finally, hold up 1 of the smallest pieces and explain that it represents $^1/_{32}$ of the surface of Earth or $^1/_8$ the land where we live. This is the amount of land available for farming. Point out that the skin on this small piece of apple represents the tiny layer of topsoil that we depend on to grow food.**
6. **Explain that because we put land to so many different uses, the amount devoted to farming has hardly changed during the past 50 years. Scientists are worried about how we will feed the world's growing population in the next 50 years.**

Activity 2: Using Land Wisely

1. **Remind the students that in Lesson 4 they were concerned with diagnosing and treating plant nutrient deficiencies in a small African village. The concern was to increase food production for the local inhabitants. In this activity, the focus broadens to consider how we can feed the entire world's population.**
2. **Display a transparency of Master 5.1, *Newspaper Articles* and cover the bottom portion so that only the top article can be read. Ask for a student volunteer to read the article aloud.**
3. **Explain to students that they will continue in their roles as agricultural experts concerned with increasing crop yields on farms. Ask students to summarize the content of the article.**

   Try to focus the discussion on the world. Most students in Canada do not have direct experience with severe hunger. Help them understand that in addition to human suffering, hunger can also lead to political instability. It is in everyone's best interest to eliminate world hunger.

   The article mentions that population growth contributes to the problem of world hunger. Although population growth is an important societal issue, please remind students that the scope of this module is limited to discussions related to agricultural practices. The article also mentions the availability of freshwater and increasing temperatures due to global warming as challenges for growing more food. If they don't understand why increasing temperatures cause lower crop yields, explain that it takes more energy for plants (and people) to maintain themselves at higher temperatures. Using humans as an example, you can point out that marathon records are usually set at cooler temperatures.
4. **Now uncover the bottom article and ask for a second volunteer to read it aloud.**

   Once again, ask students to summarize the article. Students should recognize that there are many factors that influence world hunger and that addressing the problem requires the skills of many different types of people including social scientists, climatologists, ecologists, water management experts, and agricultural experts.
5. **Divide the class into groups of 3 students. Explain that their first task is to investigate how land use is expected to affect farming in the future.**

Expectations:

Students will:

- describe the limiting factors of ecosystems, and explain how these factors affect the carrying capacity of an ecosystem.
- identify some factors related to human activity that have an impact on ecosystems (*e.g., the use of fertilizers and pesticides; altered shorelines; organic and conventional farming; urban sprawl*), and explain how these factors affect the equilibrium and survival of populations in terrestrial and aquatic ecosystems (*e.g., fertilizers change the fertility of soil, affecting what types of plants can grow in it*).
- explain how a change in one population in an aquatic or terrestrial ecosystem can affect the entire hierarchy of living things in that system.

6. **Pass out to each group a copy of Master 5.2, *Population and Land Use Graphs* and Master 5.3, *Needs of the Future.* Instruct groups to use the graphs on Master 5.2, *Population and Land Use Graphs* to help them perform a calculation on Master 5.3, *Needs of the Future* about how much farmland will be needed in the year 2050. Give groups 5 to 10 minutes to perform their calculations.**

   The numbers needed to perform the calculation are indicated on the population graph.

Expectations:

Students will:

- use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (*e.g., SI and imperial units*).
- express the results of any calculations involving data accurately and precisely.

Teacher note

The figure of 11 percent of land devoted to farming is for the world as a whole. Obviously, the corresponding figures for different countries vary considerably. This activity is designed to examine the problem of feeding the world and not to explore the conditions within individual countries.

Sample calculations for Master 5.3, *Needs of the Future:*

Part A: How much farmland is used to feed each person today?

Step 1. Use the *World Population Growth* graph on Master 5.2, *Population and Land Use Graphs* to estimate Earth's population right now: **6.6** billion people (in 2007).

Step 2. The 11 percent of land devoted to farming corresponds to 13 billion hectares of farmland.

Step 3. Divide the 13 billion hectares of farmland by the population (from Step 1) to get the number of acres of farmland per person:

13 billion hectares farmland ÷ **6.6** billion people = **2.0** hectares per person

Part B: How many acres of farmland per person will be available in 2050?

Step 1. Use the *World Population Growth* graph on Master *5.2, Population and Land Use Graphs* to estimate Earth's population in the year 2050: **8.5** billion people.

Step 2. Divide the 13 billion hectares of farmland by the population (from Step 1) to get the number of acres of farmland per person:

13 billion hectares farmland ÷ **8.5** billion people = **1.5** hectares per person

Part C: Assuming that crop yields stay the same, how much extra land will be needed for farming in 2050?

Step 1. Calculate the estimated population increase factor from now to 2050:

population in 2050 (from Part B) ÷ *population now* (from Part A) = **1.29**

Step 2. Multiply the 13 billion hectares of farmland times the population increase factor (from Step 1):

13 billion hectares farmland x ***population increase factor*** = **16.8** billion hectares farmland needed in 2050

Step 3. To find out how much extra farmland will be needed in 2050, subtract the 13 billion hectares (today's farmland) from the number of acres needed in 2050 (from Step 2):

16.8 billion acres needed in 2050 – 13 billion hectares = **3.8** billion extra hectares of farmland needed

7. **Ask each group to report the results of their calculations. Write their answers on the board or on an overhead transparency.**

   If any answers are out of the expected range, go through the calculation step by step, identify the mistake, and correct it.

8. **Review the land use for the class. If crop yields stay the same over the next 50 years, then an extra 3.8 billion hectares of farmland will need to be set aside and cultivated.**

9. **Ask the students to remember the different uses of land that they described in Activity 1: *The Big Apple*, Step 2.**

   Point to the list of land uses on the board or display the transparency where they are listed.

10. **Ask, "If billions of hectares of extra farmland are needed to feed people, where should it come from?" "What are you willing to sacrifice?"**

    Students likely will believe that people must have adequate land for the places where they live and work. They may suggest taking the land from parks or wildlife habitats. Some may suggest that if more people became vegetarians, the extra farmland could come from pastures where livestock graze.

    These questions are not intended to settle the issue. Instead, they are intended to prompt a discussion that helps students see the scope of the problem and to consider some of the difficult decisions that may lie ahead.

11. **Explain that in the next activity, they will consider how farming practices can influence land use and crop yields.**

Activity 3: Fertilizers and the Future

Teacher note

In this activity, students read about organic and commercial fertilizers (Master 5.4, *Thinking about Fertilizers)* and nutrient pollution (Master 5.6, *Nutrient Pollution*). In both masters, the information is a brief introduction to the topics. The information is not meant to be comprehensive. Rather, it is designed to challenge students' critical-thinking skills.

1. **Remind students that in Activity 2: *Using Land Wisely* they calculated that 3.8 billion extra hectares of farmland would be needed to feed the world's population in 2050. Ask, "What assumption was made in reaching this conclusion?"**

   Students' answers will vary. Some may focus on assumptions associated with the rate of population growth. This is a good answer, but you should guide the discussion to remind students that their calculations assumed that the food yields on farms would remain the same during the next 50 years.

2. **Ask, "What will be the effect of increasing the amount of food that a hectare of farmland can produce?"**

   Students should realize that if farmland becomes more productive, then fewer hectares will be required to meet the world's food needs.

3. **Explain that in their roles as agricultural experts, they are going to make recommendations to the Earth Food Bank about how to farm in the future. Explain to students that when considering the proper use of supplemental plant nutrients, they want to increase crop yields, while at the same time minimizing harm to the environment. Proper application of plant nutrients means the following:**

- **Plant nutrients are added at the right rate. Plant nutrients should be applied at the rate at which the plant can use them.**
- **Plant nutrients are added at the right time. Plant nutrients should be applied during that part of the plant's life cycle when the nutrients are needed.**
- **Plant nutrients are added at the right place. Nutrients should be applied in a location where the nutrients can be taken up by the plant's root system. This can also mean not adding plant nutrients to land that is in close proximity to waterways (e.g. within a few meters) where excess amounts of added nutrients may omove into the surface water following snowmelt or precipitation.**

4. **Explain that students need to learn more about organic and commercial fertilizers and their effects on the environment.**
   - **Pass out to half of the groups a copy of Master 5.4, *Thinking about Fertilizers* and a copy of Master 5.5, *Pros and Cons of Different Fertilizers*.**
   - **Pass out to the other groups a copy of Master 5.6, *Nutrient Pollution* and a copy of Master 5.7, *Nutrient Pollution Discussion Questions*.**
   - **Instruct the groups to read the information found on the first handout (either Master 5.4, *Thinking about Fertilizers* or Master 5.6, *Nutrient Pollution*) and to discuss within their groups their understanding. Students should relate the ideas of "right time, right place, and right rate" when considering the use of fertilizers and their impacts on the environment.**

- **Students should use the second handout (either Master 5.5, *Pros and Cons of Different Fertilizers* or Master 5.7, *Nutrient Pollution Discussion Questions*) to record their conclusions.**

Students reading about fertilizers should be able to identify three or four advantages and disadvantages of each type of fertilizer source. Students reading about nutrient pollution should be able to describe how excess nutrients can produce algal blooms that use up oxygen in the water, leading to suffocation of other plants and animals. They should be able to identify wastewater treatment facilities and industrial plants as point sources of nutrient pollution. They should identify agriculture, urban development, septic systems, and the burning of fossil fuels as nonpoint sources of nutrient pollution. Student suggestions for limiting nonpoint sources of nutrient pollution will vary. There is no simple correct answer. Look for logical responses that students can defend using evidence. The idea is to get them thinking about the multiple sources of nutrient pollution and for them to realize that limiting its effects will require a complex set of regulations, incentives, and government oversight.

Expectations:

Students will:

- assess, on the basis of research, the impact of a factor related to human activity (*e.g., urban sprawl, introduction of invasive species, overhunting/overfishing*) that threatens the sustainability of a terrestrial or aquatic ecosystem.
- identify some factors related to human activity that have an impact on ecosystems (*e.g., the use of fertilizers and pesticides*), and explain how these factors affect the equilibrium and survival of populations in terrestrial and aquatic ecosystems (*e.g., fertilizers change the fertility of soil, affecting what types of plants can grow in it*).
- analyse ways in which societal needs or demands have influenced scientific endeavours related to the environment (*e.g., the development of drought- and pest-resistant crops to address the rising global need for food*).
- use a research process to investigate environmentally sustainable methods of managing and maintaining healthy and productive agricultural zones and forests.
- explain agricultural techniques and forestry practices that aim to maintain both biodiversity and long-term productivity.

5. **After the groups have completed their tasks, ask for volunteers to read their conclusions.**
   - Make a list of the advantages and disadvantages of each type of fertilizer on the board or on an overhead transparency.
   - Discuss answers to the questions about nutrient pollution.
6. **Ask, "Why do think that some farmers use organic fertilizers and others use commercial fertilizers?"**

   Student responses will vary. Try to bring out in the discussion ideas such as that the farmers in Canada, who have good access to a variety of commercial and organic fertilizer sources, have more options than farmers in poorer countries who may have less availability and must rely on inadequate supplies of organic fertilizers that they produce and recycle for themselves. A consequence is that farmers in poorer countries often obtain lower crop yields as compared with farmers in Canada. However, farmers in Canada often preferentially choose to use organic fertilizers for a variety of other reasons, including improving the organic matter in their soils, low cost of local organic sources, etc. and these organic sources are an integral part of their agricultural operations.

Teacher note

Try to avoid getting bogged down in debating whether or not food that is organically grown is safer or tastes better than food grown using commercial fertilizers. This is not the focus of the lesson. Scientific studies have not been able to consistently find taste, health, safety differences or environmental performance between food grown using the either or both of the two sources of fertilizers.

7. **Conclude the lesson by asking students to hold on to their handouts. Explain that they will refer to them during the last lesson, when they will be making recommendations for farming in the future.**

Optional Homework Assignment 1

Instruct students to research and write a short paper describing the advantages and disadvantages of organic and commercial fertilizers. For each type of fertilizer, students should include information about

- its costs
- the fertilizer's composition,
- the fertilizer's application,
- its influence on crops yields,
- its impacts on the environment, and
- its role in agriculture, both in North America and globally.

Optional Homework Assignment 2

Instruct students to involve their parents or guardians in this activity.

- Using the world population graph on Master 5.2, *Population and Land Use Graphs,* ask students to determine the world's population when their parents or guardians were their age.
- Have students calculate the population increase from then until now.
- Have students ask their parents or guardians:
  - "What is the world's population today?"
  - "How much of Earth is used for farmland?"
- Have students, with their parents or guardians, come up with 3 ways of increasing the world's food supply.
- Instruct students to turn in a summary of the activity. It should contain
  - the world's population when the parents or guardians were the same age as the student,
  - the calculation showing the increase in population between then and now,
  - the parents' or guardians' answers to the population and farmland questions,
  - the three proposed ways of increasing the world's food supply; and
  - the parents' or guardians' signatures.

M = Involves copying a master

T = Involves making a transparency

Lesson 5 Organizer	
Activity 1: *The Big Apple* **What the Teacher Does**	**Procedure Reference**
Explain that land is a precious resource and as the world's population increases, it is important that we use land wisely.	Page 117 Step 1
Explain that land has many uses. ■ Ask, "What are some of the most important uses for land?" ■ Write student responses on the board or an overhead transparency.	Page 117 Step 2
Call attention to the apple and the knife. ■ Explain that the apple represents Earth. ■ Ask, "How much of Earth's surface do you think is devoted to farming?"	Page 117 Step 3
Cut the apple into 4 equal parts. Explain that 1 piece is about the amount of Earth that is land and not ocean.	Page 118 Step 4
Cut the $^1/_4$ piece of apple in $^1/_2$ 3 more times. Hold up 1 of the final pieces and explain that it represents $^1/_{32}$ of Earth's surface or $^1/_8$ the land surface where we live. This is the amount of land used for farming.	Page 118 Step 5
Explain that the amount of land used for farming has changed little over the past 50 years. Ask if this will be enough farmland to feed the growing human population.	Page 118 Step 6
Activity 2: *Using Land Wisely* **What the Teacher Does**	**Procedure Reference**
Remind students that in the previous lesson they were concerned with food production in a small village. In this lesson, they will consider how to feed the entire world's population.	Page 118 Step 1
Display a transparency of Master 5.1, *Newspaper Articles* and reveal the top article. ■ Ask for a volunteer to read the article aloud.	Page 118 Step 2 T
Explain to students that they will continue to work as agricultural experts. ■ Ask them to summarize the article.	Page 118 Step 3
Reveal the bottom article and ask for a volunteer to read it aloud.	Page 118 Step 4
Divide the class into groups of 3 students. Explain that they will investigate how land use is expected to affect farming in the future.	Page 118 Step 5
Give each group 1 copy of Master 5.2, *Population and Land Use Graphs* and 1 copy of Master 5.3, *Needs of the Future*. ■ Instruct groups to use the graphs on Master 5.2, *Population and Land Use Graphs* to perform the calculations on Master 5.3, *Needs of the Future*.	Page 119 Step 6 M
Ask groups to report their results. Write their answers on the board or on a transparency.	Page 120 Step 7

Lesson 5 Organizer *continued*	
Summarize the results. If crop yields remain the same, then over the next 50 years an additional 3.8 billion hectares of farmland will be needed.	Page 120 Step 8
Review the different uses of land. ■ Ask, "If billions of hectares of extra farmland are needed to feed people, where should it come from?" ■ "What are you willing to sacrifice?"	Page 120 Steps 9 and 10
Explain that they will next consider how farming practices can influence land use and crop yields.	Page 120 Step 11
Activity 3: *Fertilizers and the Future* **What the Teacher Does**	**Procedure** **Reference**
Remind students that 3.8 billion hectares of extra farmland will be needed to feed the world in 2050. Ask: ■ "What assumption was made in reaching this conclusion?" ■ "What will be the effect of increasing the amount of food that an acre of farmland can produce?"	Page 121 Steps 1 and 2
Summarize aspects of the proper application of supplemental plant nutrients. ■ Add it at the right rate, meaning at a rate at which the plant can use it. ■ Add it at the right time, meaning during that part of the plant's life cycle when the nutrients are needed. ■ Add it at the right place, meaning in a location where the nutrients can be taken up by the plant's roots.	Page 121 Step 3
Explain that students need to learn more about fertilizers and their effects on the environment. ■ Give half the groups 1 copy of Master 5.4, *Thinking about Plant Nutrients* and 1 copy of Master 5.5, *Pros and Cons of Different Fertilizers*. ■ Give the other groups 1 copy of Master 5.6, *Nutrient Pollution* and 1 copy of Master 5.7, *Nutrient Pollution Discussion Questions*. ■ Instruct students to read the information on the first handout, discuss it, and record their conclusions on the second handout.	Page 121 Step 4 M
Ask for volunteers to read their conclusions. ■ List advantages and disadvantages of each type of fertilizer on the board or on a transparency. ■ Discuss answers to the questions about nutrient pollution.	Page 122 Step 5
Ask, "Why do you think that some farmers use organic fertilizers and others use commercial fertilizers?"	Page 122 Step 6
Instruct students to keep their handouts. They will refer to them in the final lesson.	Page 123 Step 7

The Daily Herald

SPECIAL EDITION DECEMBER 14

Study Forecasts Future Food Shortage

A new study published in the Journal of World Agriculture raises concerns that in the future there will not be enough food for the world's growing population. The study was carried out by an international group of scientists with support from the Earth Food Bank. According to the study, the population of the world is increasing by about 80 million people each year.

To feed the growing population, crop yields will need to increase significantly. The researchers listed many factors that limit food production but singled out two for special consideration. First, the amount of freshwater available for farming is projected to limit food production. Second, higher temperatures around the world are already causing large losses in grain yields among the world's major producers. The study concluded by recommending that the Earth Food Bank sponsor a program dedicated to setting priorities and establishing policies that will enable all of the world's people to be fed.

The Daily Herald

MORNING EDITION MARCH 17

Earth Food Bank to Hold Meeting on Food Production

In response to a recent international study on population and food production, the secretary general of the Earth Food Bank has announced that it will sponsor a series of two-weeklong conferences next summer to address world hunger. Attendees at each conference will discuss a different aspect of the problem and make recommendations for meeting the world's food needs. According to the study, the four major aspects of the problem are

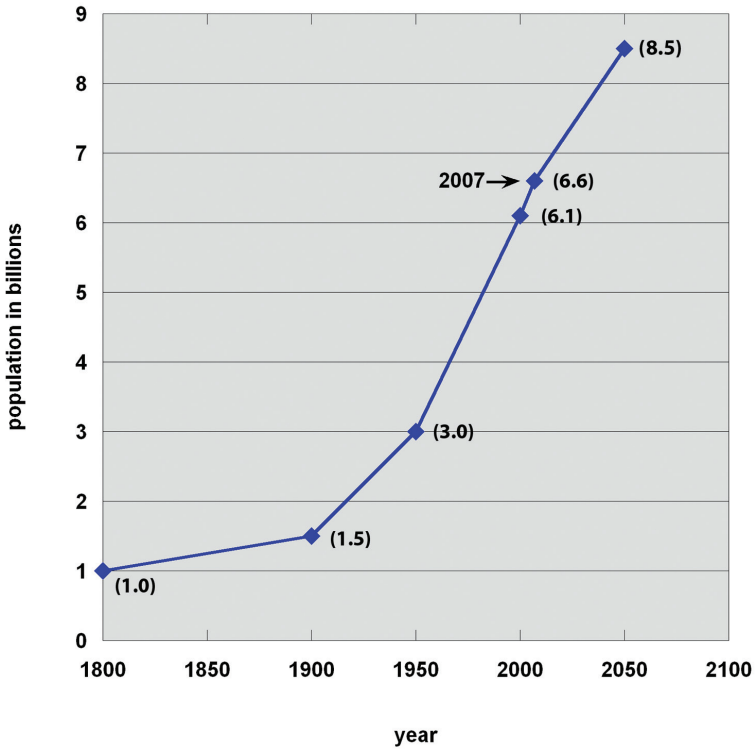
- reducing carbon emissions that contribute to increasing Earth's temperature,
- stabilizing population growth,
- making better use of our water resources, and
- increasing the crop yields on farms.

An international group of experts will attend each conference. The experts will submit a report to the secretary general that describes their recommendations. Scientists from Humanity Against Hunger will organize the conference on increasing crop yields. These scientists have experience applying modern agricultural practices in developing countries.

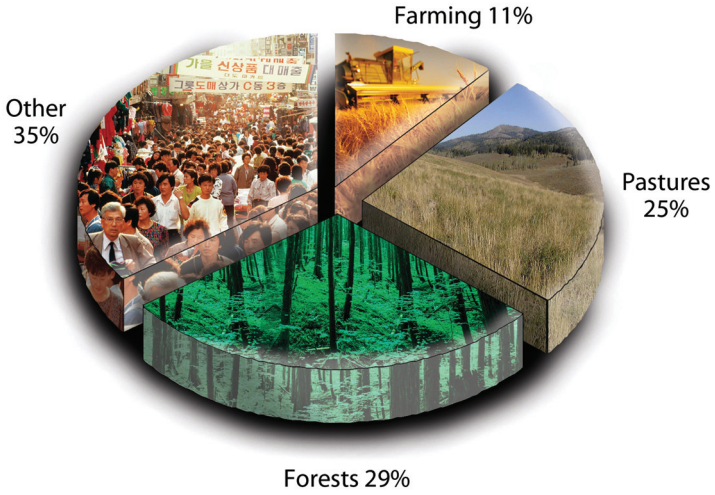
Name

Date

World Population Growth



World Land Use



Master 5.3, *Needs of the Future*

Name _____

Date _____

Part A: How much farmland is used to feed each person today?

Step 1. Use the *World Population Growth* graph on Master 5.2, *Population and Land Use Graphs* to estimate Earth's population right now: _____ billion people.

Step 2. The 11 percent of land devoted to farming corresponds to 13 billion hectares of farmland.

Step 3. Divide the 13 billion hectares of farmland by the population (from Step 1) to get the number of hectares of farmland per person:

13 billion hectares farmland ÷ _____ billion people = _____ hectares per person

Part B: How many hectares of farmland per person will be available in 2050?

Step 1. Use the *World Population Growth* graph on Master 5.2, *Population and Land Use Graphs* to estimate Earth's population in the year 2050: _____ billion people.

Step 2. Divide the 13 billion hectares of farmland by the population (from Step 1) to get the number of hectares of farmland per person:

13 billion hectares farmland ÷ _____ billion people = _____ hectares per person

Part C. Assuming that crop yields stay the same, how much extra land will be needed for farming in 2050?

Step 1. Calculate the estimated population increase factor from now to 2050:

population in 2050 (from Part B) ÷ population now (from Part A) = _____

Step 2. Multiply the 13 billion hectares of farmland times the population increase factor (from Step 1):

13 billion hectares farmland x *population increase factor* =
_____ billion hectares farmland needed in 2050

Step 3. To find out how much extra farmland will be needed in 2050, subtract the 13 billion hectares (today's farmland) from the number of hectares needed in 2050 (from Step 2):

_____ billion hectares needed in 2050 – 13 billion hectares = _____ billion extra hectares of farmland needed

Master 5.4, *Thinking about Fertilizers*

Farmers that fertilize their crops can use either organic or commercial fertilizers, or a combination of the two. As the name suggests, organic fertilizer comes from once living material such as plants or animal waste. Organic fertilizers that come from plants versus animals behave differently in the environment, so a distinction is made between the two. Manure-based fertilizer is the type used by most farms.

Commercial fertilizers are produced through industrial processes and contain nutrients in forms that crop plants can use immediately, without the action of decomposing microbes. The amount of each nutrient contained in commercial fertilizers is known precisely. This means that farmers know the exact amounts of nutrients applied to plants. Commercial fertilizers are labelled with three numbers that describe the amounts of nitrogen, phosphorus, and potassium that it contains. For example, a fertilizer labelled 15-5-10 contains 15 percent nitrogen, 5 percent phosphorus (P_2O_5), and 10 percent potassium (K_2O). All other plant nutrients and accompanying compounds are often also listed. In general, commercial fertilizers allow the farmer more control over plant nutrition than organic fertilizers because when using commercial fertilizers, the amounts of nutrients are precisely known and they are released in a more predictable way.

Organic fertilizers of all types contain high levels of organic matter, which is increasingly attractive to consumers. They encourage the use of local natural resources and the recycling of farm and other biosolid wastes. In general, organic fertilizers, when available, add valuable organic material to the soil, when available. Transportation costs can be high compared to commercial fertilizers due to lower nutrient concentrations, and the crop requiring nutrient ratios may not be possible.

Plant-based fertilizers include plant compost and cover crops (also called green manure). Cover crops such as rye, alfalfa, or clover can be planted immediately after a crop harvest to hold the soil in place, preventing erosion and nutrient loss. They can represent an important nutrient source because they absorb mineral nutrients that might be subject to loss and later, when ploughed, decompose and the nutrients become available to subsequent crops. Some legume crops (e.g field peas, lentils and clovers) are grown specifically to add nitrogen to the soil as the symbiotic bacteria living in the legume root nodules convert nitrogen gas (N_2) into plant available ammonium (NH_4). These plant-based nutrient sources are used on a small scale in comparison to animal manure-based fertilizers. Plant-based organic fertilizers usually contain some nutrients that dissolve in water, but most of the nutrients are released slowly as microbes in the soil break down the organic material into forms that the plant roots can absorb. This is an advantage when fertilizers are added infrequently during the growing season.

Manure-based fertilizers are by far the dominant form of organic fertilizer used on farms. The use of manure fertilizer saves money when they are used locally, and helps solve the problem of disposing of animal wastes.

The environmental problems that can be associated with fertilizers vary with the type of fertilizer. Both manure-based organic fertilizer and commercial fertilizers may runoff the land or leach into groundwater because they tend to move with water. In the case of manure-based organic fertilizers, the nitrogen component is more easily lost to the air as ammonia gas emissions. In fact, over 50 percent of the nitrogen in manure-based fertilizer can be lost as ammonia emissions if the manure is not incorporated into the soil. Loss of manure-based nutrients to the environment tends to occur when they are over-applied to fields near the livestock facilities

Plant-based organic fertilizers present the fewest environmental challenges, but are not widely used.

While commercial fertilizers can present the same environmental concerns, their more precise nutrient content and release, and ease of handling reduce the farmers' operational challenges to proper management. Commercial fertilizers do, however, present greater risks to the environment if improperly applied, due to their much higher nutrient content. Their higher cost also leads to a heightened attention to proper management by farmers.

While specific management techniques for the different sources of plant nutrients vary, in all cases proper management is essential to efficiently optimize crop production and minimize risks to the environment. No matter what type of fertilizers are used, it is important to follow best management practices designed to grow affordable, healthy crops while, at the same time, protecting the environment.

Name
Date

Organic Fertilizers

Advantages	Disadvantages

Commercial Fertilizers

Advantages	Disadvantages

Master 5.6, *Nutrient Pollution*

When we think of environmental pollution, we think of chemicals from industry and car exhaust fouling our air and water. Although nutrients occur naturally, they, too, can be a source of pollution. You should recall that all living things require nutrients, but too much of a nutrient can harm terrestrial and aquatic ecosystems. Excessive amounts of nutrients in our waterways are bad for the environment because they can lead to explosive growth of aquatic organisms such as phytoplankton and algae. The organisms eventually die and sink to the bottom, where they are decomposed by oxygen-consuming bacteria. These bacteria can use up the available oxygen and cause fish to suffocate. There are large areas of estuaries and coastal zones worldwide that suffer from this problem.

Excess nitrogen is also accumulating in groundwater and the air. High levels of nitrate can affect human health if it accumulates locally in groundwater. A form of nitrogen gas that is increasing in the atmosphere globally is nitrous oxide (N_2O). Nitrous oxide is a greenhouse gas and contributes about 6 percent to current global warming. Nitrous oxide is emitted from all ecosystems naturally, but it is emitted at high rates from fertilized agricultural fields, animal feed lots, and the burning of plant biomass (e.g. tropical forest fires). Management practices can reduce these losses.

Nonpoint source pollution refers to polluted runoff and groundwater. When water from any source such as rain or irrigation water for crops washes over land, it picks up both soil particles that include nutrients and dissolved plant nutrients. These contaminants find their way into waterways either directly or through storm drains. In contrast to nonpoint sources are point sources of pollution. Point source pollution is comes from a specific source such as a factory or wastewater treatment plant.

In urban areas, such point sources are often the main contributors to nutrient pollution. Urban areas also are affected by nonpoint source pollution. For example, the burning of fossil fuels by cars and industry releases nitrogen compounds into the air. These compounds fall to the surface with rain and contribute to nutrient pollution.

As suburban areas have grown, they have moved beyond the reach of city sewer systems. Homes in many areas use septic systems that release nutrients from wastewater into the ground. Also, an increase in the amount of paved area increases runoff.

Farmers also can contribute to the problem. Improper application of organic and commercial fertilizers can send excess nutrients into the environment. Agriculture is often the major nonpoint source of nutrient pollution in rural areas, but not urban areas.

Antipollution laws and some voluntary efforts, including mandatory and voluntary nutrient management plans, are helping reduce nutrient pollution by farmers and from point sources such as factories. Nonpoint sources represent the largest pollution threat to our waters, but they are difficult to identify and control. Can you think of ways to limit nutrient pollution from nonpoint sources?

Master 5.7, *Nutrient Pollution Discussion Questions*

Name _____

Date _____

Discussion Questions

1. Why are excessive amounts of nutrients bad for the environment?

2. What is the difference between a point source and a nonpoint source of nutrient pollution? List examples of each type of source.

3. What are some ways to limit nutrient pollution from nonpoint sources?