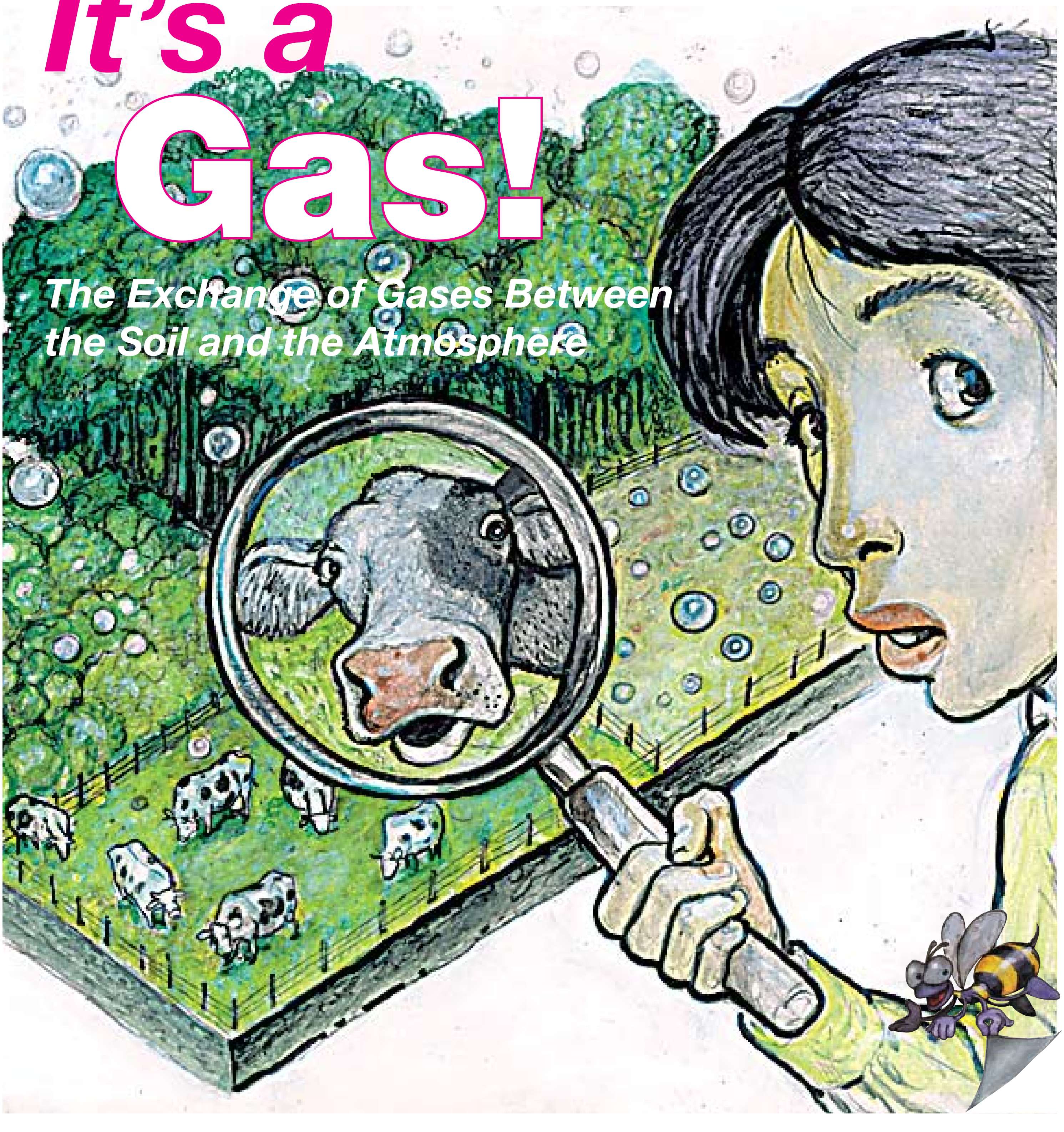
NATURAL INQUIRER

CLIMATE CHANGE EDUCATION COLLECTION • FALL 2008

It's a Gas!

The Exchange of Gases Between the Soil and the Atmosphere



Natural Inquirer

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The Exchange of Gases Between the Soil and the Atmosphere

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Contents

Feature

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About the *Natural Inquirer*

Scientists usually report their research using a standard written form, called a scientific article. When a collection of articles are published together, the booklet is called a science journal. When a single article is published, the booklet is called a monograph.

This *Natural Inquirer* is a monograph and includes one scientific article. This monograph was created so that scientists can share their research with you and with other middle school students. The monograph tells you about scientific research conducted by scientists in the Forest Service. If you want to know more about the Forest Service, you can read about it on the inside back cover of this monograph, or you can visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org.

All of the research in the *Natural Inquirer* is concerned with nature, such as trees, forests, animals, insects, outdoor activities, and water. First, you will "meet the scientist" who conducted the research. Next, you will read something special about science and about the natural environment. You will also read about a specific research project investigating climate change. Then, YOU become the scientist when you conduct the FACTivity associated with the article. Don't forget to look at the glossary and the special sections highlighted in each article. These sections give you extra information.

At the end of each section of the article, you will find a few questions to help you think about what you have read. The questions should help you to think more about the research. Your teacher may use these questions in a class discussion.

Welcome to the Natural Inquirer Climate Change Education Collection!

As a global citizen, you know that people around the world share similar environmental concerns. The changing climate is one concern shared by people everywhere. Some Forest Service scientists are interested in studying climate change and its relationship to forests, grasslands, air, and water. You will learn about one of these studies in this monograph.

As you know, scientific research is a continual process of discovery. Forest Service scientists are learning much about climate change, but there is still much we do not know.

This monograph is part of a collection of articles describing climate change research. You can order any of the *Natural Inquirer* monographs or journals by visiting http:www.naturalinquirer.org. The monographs and journals are free of charge.

Educators: Review "Note to Educators" on page 10 before using this *Natural Inquirer* monograph.

http://www.naturalinquirer.org

It's a Gas!

The Exchange of Gases Between the Soil and the Atmosphere

Meet Dr. Keller *(with hat)*:
I like being a scientist because I get to follow my natural curiosity to learn how the Earth system works. My work is split between the field, the office, and the laboratory and I have a great deal of independence. I love to learn new things.

Dr. Keller

Thinking About Science

Chemistry is the science of the building blocks of all matter. Atoms are the most basic building block. Molecules are combinations of two or more atoms of the same chemical element. All matter is built from over 100 chemical elements. Examples of elements are nitrogen, hydrogen, oxygen, and carbon. Compounds are made up of two or more elements. To make it easier

Glossary:

gaseous (**gash** us): In the form of gas.

greenhouse effect (**gren** howls e **fekt**): Warming of the Earth's surface that occurs when the sun's heat is trapped by the atmosphere.

climate (**kli** met): The average condition of the weather at a place.

bacteria (bak **ter** e uh): Living things that only have one cell and can only be seen using a microscope.

specialization (**spesh** ul i **za** shun): Special study of something or working only in a special topic or area.

compact (käm **pakt**): To pack closely and firmly together.

porous (**poor** us): Full of pores or tiny holes through which water, air, etc., may pass.

sample (**sam** pool): A part or piece that shows what the whole group or thing is like.

anaerobic (**an** ä **ro** bik): Existing in the absence of oxygen.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

to imagine, think about the alphabet. Atoms are like different letters. There could be “A” atoms, “B” atoms, and “C” atoms, for example. Elements are like a single letter, such as A, I, or T. Molecules are like strings of the same letter (or element), such as BBB or MMMM. Compounds are like words, which are made from different letters (or elements). When elements interact and become compounds, their structure changes. Elements can form an almost limitless number of compounds, just as letters can form an almost limitless number of words. These compounds can be solid, liquid, or gas. Some scientists study the structure and behavior of *gaseous* compounds. In this study, the scientists were interested in studying the gaseous compounds that go into the atmosphere as greenhouse gases.

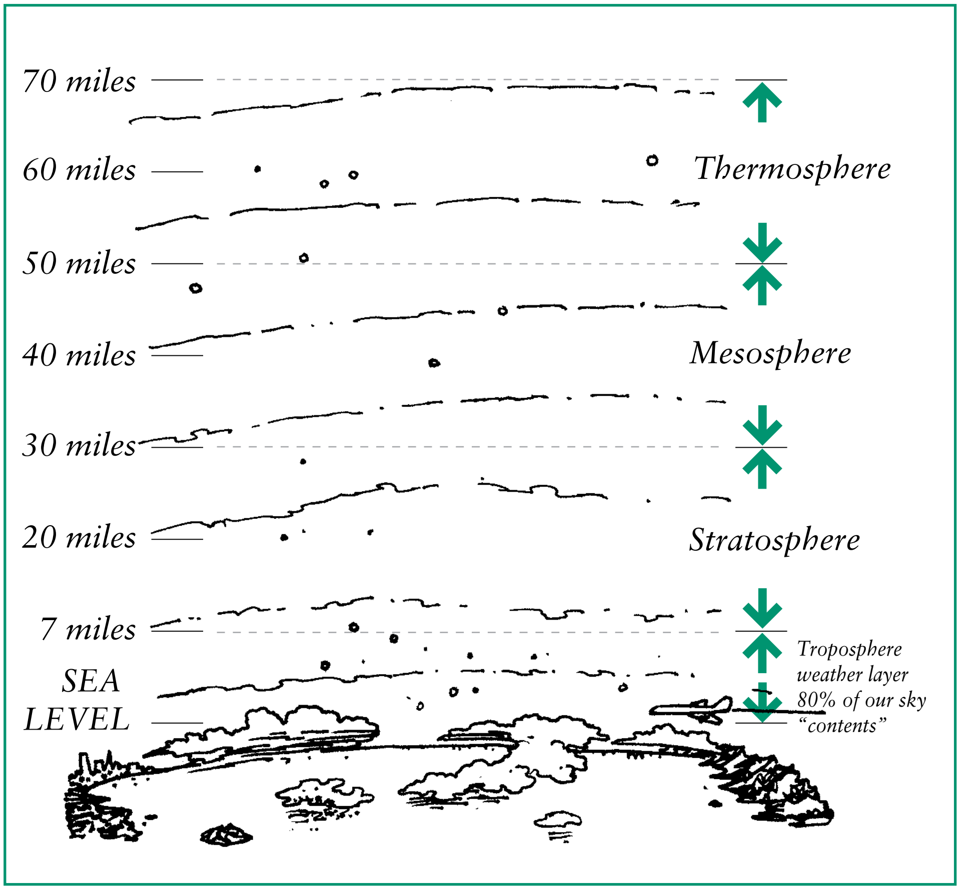


Figure 1. The Earth’s atmosphere. The troposphere is the section of our atmosphere reaching from sea level up to 7 miles. Most clouds are contained within the troposphere. When you fly somewhere in a jet, you are flying through the middle and upper portions of our troposphere.

Thinking About the Environment

The *greenhouse effect* is caused by certain gases that act like glass in a greenhouse. They reflect heat in the atmosphere back down to earth (**Figure 1**). The amount of heat trapped in the atmosphere can vary, depending on the type of gas and how long it stays in the atmosphere. The major greenhouse gases are water vapor, carbon dioxide (**kär** bun di **ox** id), methane (**meth** an), nitrous (**ni** trus) oxide, and chlorofluorocarbons (**klôr** o **flôr** o **kär** buns), also called CFCs. We need a certain level of greenhouse gases to maintain a liveable *climate* on Earth. If we had too small an amount of greenhouse gases, the Earth’s climate would get too cold. If we get too great an amount of greenhouse gases, the Earth’s climate will get too warm. Human activities, such as burning fossil fuels like petroleum, can create greenhouse gases. The scientists in this study looked at greenhouse gases from another perspective. They looked at how human activities have enabled soil *bacteria* to increase the amount of nitrous oxide in the atmosphere.

Introduction

Tropical forests are sometimes cut down so that humans can use the trees for wood and other products. Then, the cleared land is made into a pasture so that cattle can be raised for human consumption. When forest land becomes pasture, the soil changes. It becomes more *compacted* and less *porous*. (Can you think of why this might happen? Think about the size and weight of cattle.) Previous research had shown

Thinking About Ecology

Often, scientists study one particular event or object. While such *specialization* helps scientists to understand a lot about that one event or object, it does not always help them to understand how that event or object relates to other events or objects. Ecologists (e **käl** uh jists) are scientists who study how living things relate to each other and to nonliving things. In this study, the ecologists were studying the nitrogen cycle (**Figure 2**). The nitrogen cycle explains the relationship of the element nitrogen with other elements, and with plants, animals, and bacteria. Bacteria are important in the cycle, because they convert nitrogen from the atmosphere into forms that plants can use such as nitrates and ammonia. These compounds are used by plants to make other compounds such as protein. Animals who eat plants can use the protein from the plants. Bacteria living in soil convert animal wastes and dead material from plants back into nitrogen compounds. The nitrogen is released back to the atmosphere, and the cycle begins again. This is an example of how life depends on relationships between living and nonliving things. What are some examples of how your life depends on living and nonliving things?

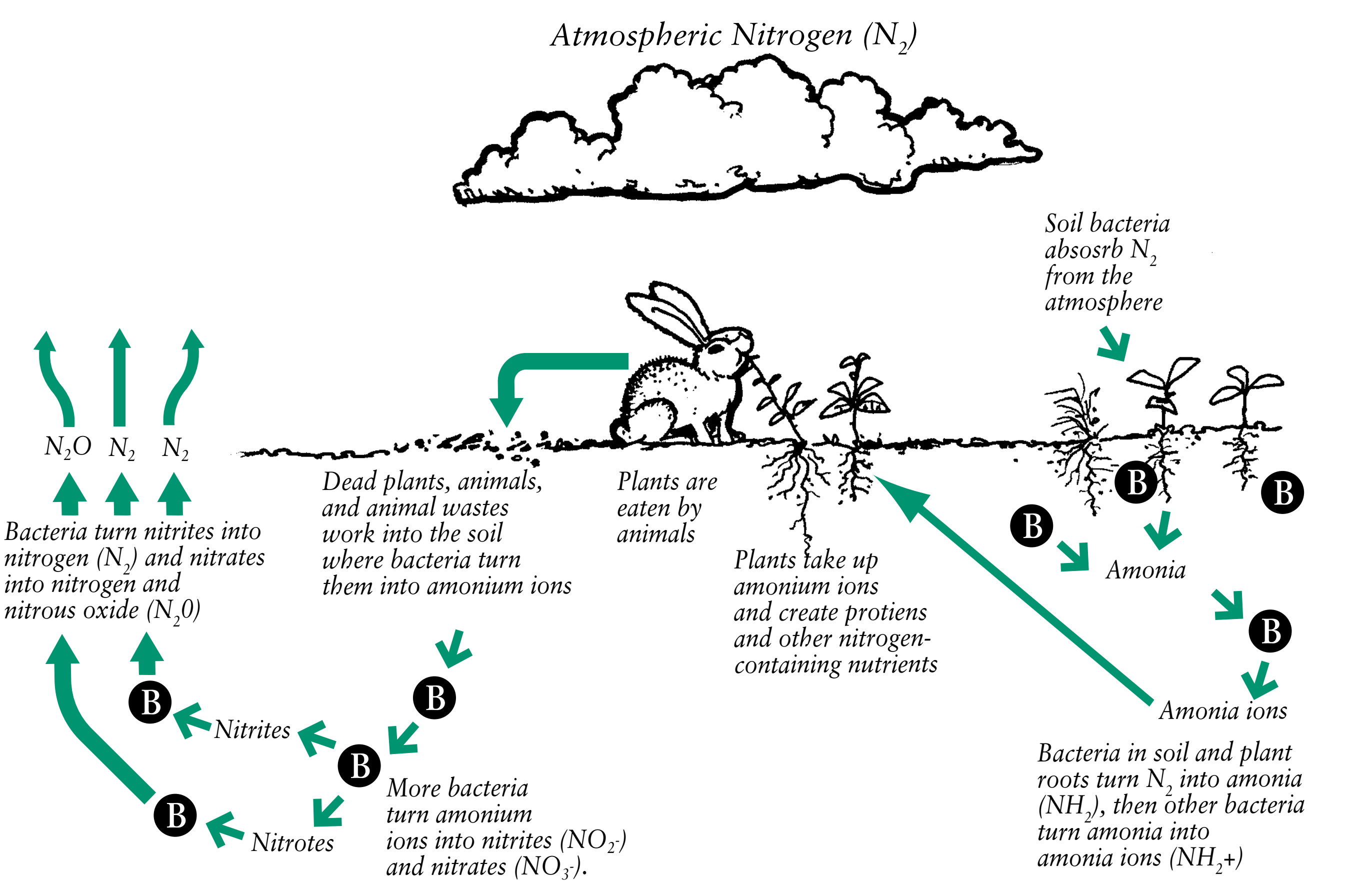


Figure 2. The nitrogen cycle.

that pasture soils release more greenhouse gases than forested land. Sometimes pastures are abandoned after a while. This is often because the soil can no longer produce enough plants to support the cattle. When pastures are abandoned, the forest begins to grow again. No one knew whether soils from these young forests would begin to release less greenhouse gases as the forest grew again. That is the question the scientists wanted to answer.

Reflection Section

- What is the question the scientists wanted to answer? What is the bigger problem their research might help to solve?

- Do you think the scientists needed to visit and study young tropical forests, or could they do all of their research inside a laboratory? Why or why not?

Method

The scientists selected four types of areas to study. They studied old tropical forests, young tropical forests, pastures that were currently being used for raising cattle, and recently abandoned pastures (**Figures 3-5**). They selected three different areas of each type to study as examples. (How many total areas did they study? Multiply 4 types of areas times 3 examples each.) Then, they picked eight spots in each area where they measured the amount of nitrous oxide (N_2O) in the

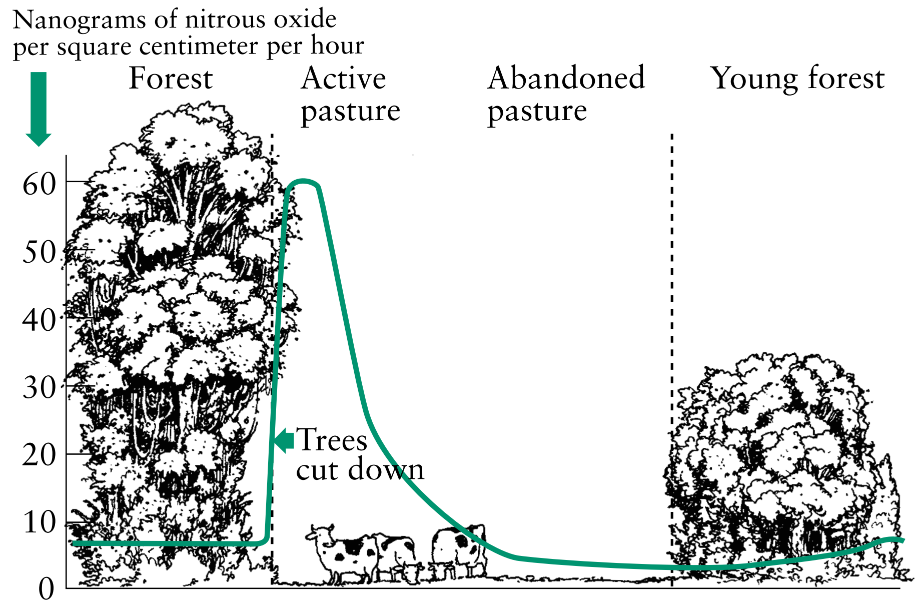
Figures 3-5. An old tropical forest, a current pasture, and a young tropical forest.

soil. (How many total spots did they measure? Multiply 12 X 8.) The scientists measured the amount of nitrous oxide at the top level of the soil at each spot once a month for 12 months. (How many total measurements did they collect? Multiply 12 X 8 X 12. How many measurements did they collect for each type of area? Divide the total measurements by the number of types.) The scientists collected *samples* of the gases that were in the soil by placing an instrument 2 centimeters into the soil (**Figure 6**). (To find out how many inches that is, multiply 2 X .393.) They took the gaseous samples back to a laboratory. There they measured now much nitrous oxide was in the samples collected from the top level of the soil.

Reflection Section

- Why do you think the scientists studied all four types of areas, instead of just studying young tropical forests?

Figure 6. Photograph of equipment used to collect nitrous oxide gas.



A nanogram is one-billionth of a gram. That's not very much weight! If you took a frito (Fritos® brand corn chip) and smashed it into 1 billion pieces, each piece would weight about one nanogram. At the rate of 60 nanograms per hour, about 60 grams of nitrous oxide would be released in an area 1 kilometer (.621 miles) square. In 1 day, 1,440 grams of nitrous oxide would be released in that square kilometer. How many grams would be released in a month? Although a nanogram is not much weight, you can see that over time, nanograms of nitrous oxide can add up!

Figure 7. The amount of nitrous oxide found in the top layer of the soil over the period of 1 hour in four types of tropical land.

- Do you think that the scientists found that more, the same, or less nitrous oxide was in the soil of young tropical forests compared with the soil in the pasture being used by cattle? Why?

Results

The scientists discovered that the amount of nitrous oxide near the top of the soil was different in the four types of areas (**Figure 7**). The amount of nitrous oxide is low in old tropical forests. When forests are cleared and used for pasture, the amount of nitrous oxide near the soil's surface rises. As pastures are abandoned and young forests begin to grow, the amount of nitrous oxide at the surface drops to levels even below the old forest levels. The scientists think that water is the key to understanding this pattern. Because cattle hooves compact the soil, pasture land is less able to absorb and drain water. This condition encourages *anaerobic* bacterial activity on plant and animal wastes near the soil's surface. This results in an increased amount of nitrous oxide near the soil's surface, which is then released into the atmosphere.

Reflection Section

- What are two things happening in tropical pastures that might be increasing the amount of nitrous oxide being released into the atmosphere?

- The scientists measured the amount of nitrous oxide 2 centimeters below the surface of the soil. Do you think that same amount of nitrous oxide is being released into the atmosphere? Why or why not?

Discussion

The scientists discovered that nitrous oxide is being released into the atmosphere as a part of the nitrogen cycle. They do not know, however, what causes bacteria to turn some ammonium ions into nitrous oxide and others into nitrogen. Nitrogen is a necessary gas in the atmosphere, but nitrous oxide is a greenhouse gas that could cause harm in great amounts. There is still a lot to learn about tropical soils and greenhouse gases. This research shows that humans impact the Earth in ways that we may not be able to see. By making decisions to manage land in different ways, we affect what happens now and what will happen in the future.

Reflection Section

- What other things do you know about the effect of greenhouse gases?

- Do you think that no matter where they are on the planet, pastures cause more nitrous oxide to be released than would happen if the land were a forest? Why or why not?

Discovery FACTivity

In this FACTivity, you will answer the question: What are the similarities between a glass jar with soil and the Earth's atmosphere? The method you will use to answer this question is this: Get two thermometers, a large clear glass jar with a lid (be careful!), and 1 cup of dark soil. Put the soil into the glass jar to a depth of about 4 centimeters (or about 2 inches). Put a thermometer upside down in the jar, and close the lid. Turn the glass jar over, so that the soil is at the lid and the thermometer is right side up. Place the jar in the sunlight or under a high-intensity bulb for 1 hour. Place the second thermometer near the jar.

At the end of the hour, record the temperature outside of the jar using the second thermometer. Record the temperature of the air inside of the glass jar. Compare the two temperatures. Then consider the following questions:

- What part of Earth does the air inside of the jar represent?
- What part of the Earth does the glass represent?
- What part of the Earth does the black dirt represent?

You will see that the soil is heated by the light, which then radiates the heat back into the air where it is trapped by the glass. You have created a greenhouse effect! Now see if you can answer the question posed at the beginning of this FACTivity.

This FACTivity was adapted from Rodriguez, N., Kampen, A., and Dufresne, M. (2000). It's your planet: A study of global warming. An interdisciplinary curriculum designed for middle school students and their exploration of global warming. Visit this Web site for more information and activities: http://www.classtech2000.com/archno2/SessionB/Jesuit/gwarming.htm

From Keller, M. & Reiners, W. A. (1994). Soil-atmosphere exchange of nitrous oxide, nitric oxide, and methane under secondary succession of pasture to forest in the Atlantic lowlands of Costa Rica. *Global biogeochemical cycles*, 8(4): 399-409.

Note to Educators

The mission of the Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. For more than 100 years, our motto has been caring for the land and serving people. We recognize our responsibility to be engaged in efforts to connect youth to nature and to promote the development of science-based conservation education programs and materials nationwide. We have developed the *Natural Inquirer* Climate Change Education Collection to help you and your students better understand climate change.

Forest Service researchers have studied the impacts of climate change and air pollutants on forests and grasslands for more than 30 years. This research has identified climate change trends and subsequent effects to ecosystems across the United States and worldwide. For their research contributions to the Intergovernmental Panel on Climate Change (IPCC) Report, 13 Forest Service scientists were recipients of the Nobel Peace Prize in 2007. The Nobel Committee recognized "efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change."

The articles in the Climate Change Education Collection will introduce students to several of these scientists and their climate-change-related research. Students will learn about the scientific process used by the scientists and will be engaged in hands-on activities on climate change topics such as the carbon cycle, invasive species, vegetation changes, and urban and world forests.

As teachers of science, you want your students to acquire abilities that will enable them to conduct scientific inquiry, and you want them to gain an understanding of the scientific inquiry process. Scientific inquiry can best be taught by integrating minds-on and hands-on experiences. Over time, such experiences encourage students to independently formulate and seek answers to questions about the world we live in. As educators, you are constantly faced with engaging your students in scientific inquiry in new and different ways. In an age of abundant technology, standard teaching strategies can become monotonous to today's learners. The *Natural Inquirer* provides a fresh approach to science and a view of the outside world that is larger than the classroom and can still be used while in the school setting.

The *Natural Inquirer* is a science education resource journal to be used with learners from Grade 5 and up. The *Natural Inquirer* contains articles describing environmental and natural resource research conducted by the Forest Service, U.S. Department of Agriculture scientists and their cooperators. These are scientific journal articles that have been reformatted to meet the needs of middle school students. The articles are easy to understand, aesthetically pleasing to the eye, contain glossaries, and include hands-on activities. The goal of the *Natural Inquirer* is to stimulate critical reading and thinking about scientific inquiry and investigation while learning about ecology, the natural environment, and natural resources.

The Format of a *Natural Inquirer* Article: Each *Natural Inquirer* article follows the same format. *Natural Inquirer* articles are written directly from a published science article, and all have been reviewed by the scientists for accuracy. Each article contains the following sections, which you may introduce to your students as they read:

Meet the Scientists: Introduces students to the scientists who did the research. This section may be used in a discussion of careers in science.
Glossary: Introduces possibly new scientific or other terms to students. The first occurrence of a glossary word is italicized in the text.
Thinking About Science: Introduces something new about the scientific process, such as a scientific habit of mind or procedures used in scientific studies.
Thinking About the Environment: Introduces the environmental topic being addressed in the research.
Introduction: Introduces the problem or question being addressed by the research.
Method: Describes the method used by the scientists to collect and analyze their data.
Findings: Describes the results of the analysis.
Discussion: Discusses the findings and places them into the context of the original problem or question.
Citation: Gives the original article citation.
FACTivity: Reinforces an aspect of the research through a hands-on activity.

Science Education Standards and Evaluations: In the back of the monograph, you will find a list that allows you to identify articles by the National Science Education Standards they address. You and your students may also complete evaluation forms online by visiting **http://www.naturalinquirer.org.** If you have any questions or comments, please contact:

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(Please put "Educator Feedback" in the subject line)

Educator Resources:
From the Web site, you can read and download lesson plans, word games, and other resources to help you use the *Natural Inquirer* in your classroom. You can also view and download a year-long lesson plan aimed at helping your students learn about the scientific process.

Visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org.

For more climate change information, visit: http://www.fs.fed.us/climatechange/

Lesson Plan for This Monograph

Time Needed:
One class period (50-60 minutes)

Materials Needed:
- 1 piece of plain white 8.5 X 11" paper for each student; 1 piece of plain paper for each group of 4 students
- 3 X 5" sticky notes (enough for at least 7 per student)
- A monograph for each student

In class the day before:
Give each student a copy of the monograph, a piece of plain paper, and three sticky notes. The sticky notes should be placed on the paper and labeled "Science," "Environment," and "Prediction."

For homework:
Ask them to read "Thinking About Science" and "Thinking About the Environment." After they read each section, have them write the main idea of the section on the correct sticky note. On the third sticky note, they should predict what they think the article will address. Ask them not to read ahead in the monograph, but to use clues from the two sections to help them predict. They should also review the glossary before coming to class.

In class:
Introduce the *Natural Inquirer* monograph to the class. Include information about the sections they will be reading. (See "Note to Educator, The Format of a *Natural Inquirer* Article" on page 10.) (5 minutes)

On your whiteboard or clean chalkboard, label three areas "Science," "Environment," and "Prediction." Have each student place his or her sticky note in the correct area. Have a few students read some of the notes, one section at a time. Hold a class discussion about the similarities and differences of the notes in each section. Have students identify what clues they used to predict what the article would address and how the scientists might address it. (8 minutes)

Read "Meet the Scientists," "Introduction," "Method," "Findings," and "Discussion" Sections as a class. When you reach the end of each section, have students write the main idea of the section on a labeled sticky note. For now, skip the reflection questions. When the article has been completely read and all sticky notes completed, have students place their sticky notes on the whiteboard, under the correct heading (Introduction, Method, Findings, Discussion). (18 minutes)

Now, have each student select one sticky note from each category. They must not select their own sticky note. Place students in groups of four. Each group should compare and contrast their sticky notes for each section. On a sheet of paper, one student will write the four headings and under each heading, write the main ideas of each section as agreed on by the group. Each section's main ideas should be between 1 to 4 sentences long. (5 minutes)

Have each group read its main ideas for one or more sections (based on available time). Hold a class discussion to compare and contrast what each student group reported. (5 minutes)

Hold a class discussion about the research they have just read. What might happen to the environment in the future, given what they have learned? (5 minutes)

Make a list of actions they can take to reduce their carbon footprint (4 minutes). Examples include:

- Walk and bike more, ride in a car less.
- Eat more local produce; buy from local farmers' markets.
- Plant and maintain trees.
- Turn down the thermostat by 1-2 degrees in the winter.
- Turn up the thermostat by 1-2 degrees in the summer.
- Turn off appliances when not in use.
- Turn down the temperature in the hot water heater.
- Unplug your phones, etc., as soon as they have charged.
- Only do full loads in the dishwasher and clothes washer.
- Hang out clothes to dry.
- Consolidate car trips.
- Use energy-efficient light bulbs.
- Take shorter showers.

Day 2 (Optional): Do the FACTivity.

Lesson Plan Extension (This can be done in place of the FACTivity or as an extension on Day 3 if time allows.)

For homework, have students complete the reflection questions. They can use the same "sticky note" process to record their answers. In class on Day 2 (or 3, if you have done the FACTivity on Day 2), discuss their answers as a class. You may use the whiteboard to "mix up" the answers in the same manner as Day 1.

Reflection Section Answer Guide

Introduction

- **What is the question the scientists wanted to answer? What is the bigger problem their research might help to solve?** The bigger problem scientists might help to solve is how can we help reduce and slow the release of greenhouse gases into the atmosphere.

- **Do you think the scientists needed to visit and study young tropical forests, or could they do all of their research inside a laboratory?** Scientists need to visit and study young tropical forests because they needed actual measurements of greenhouse gases that are occurring in tropical forests. **Why or why not?** A laboratory setup would not suffice in this situation to get accurate results.

Methods

- **Why do you think the scientists studied all four types of areas, instead of just studying young tropical forests?** A comparison is necessary to give meaning to the data. The scientists studied all four types of areas to be able to describe how much nitrous oxide was being released in each area. The data were compared from each area to find out the rates nitrous oxide was released. If the scientists only studied one site, the data would be meaningless to answer the research question.

- **Do you think that the scientists found that more, the same, or less nitrous oxide was in the soil of young tropical forests compared with the soil in the pasture being used by cattle?** Each student's experience should help him/her answer this question. Have the students describe why they gave their answer with proper justification. **Why?** The young forest should contain less nitrous oxide in the soil than the pasture because more biotic activity is occurring in the young forest soil

Findings

- **What are two things happening in tropical pastures that might be increasing the amount of nitrous oxide being released into the atmosphere?** (1) Cattle hooves compact the soil, resulting in pasture land less able to absorb and drain water. (2) Anaerobic bacterial activity increases in pastures when animal waste is near the soil's surface.

- **The scientists measured the amount of nitrous oxide 2 centimeters below the surface of the soil. Do you think that same amount of nitrous oxide is being released into the atmosphere? Why or why not?** Because soils do not release all of the gases they hold, the amount of nitrous oxide released into the atmosphere is not necessarily the same amount as that measured in the soil.

Discussion

- **What other things do you know about the effect of greenhouse gases?** This answer depends on the student's science experience. Have students discuss the topic with each other in a class discussion. Discussion topics include local and global implications of climate change and effects on the atmosphere from human activities, such as use of fossil fuels, pollution, and deforestation. Your class can also discuss observed and potential future effects of climate change on plant and wildlife species.

- **Do you think that no matter where they are on the planet, pastures cause more nitrous oxide to be released than would happen if the land were a forest? Why or why not?** Students should give their answer and use logic to back it up. Research shows that the amount of nitrous oxide released from pastures compared with forests is highly variable. Studies have shown different results in other areas. In some areas, pastures release more nitrous oxide than forests. In others, forests release more nitrous oxide. Scientists believe the amount of water held by pasture soils may be related to the amount of nitrous oxide released.

It's a Gas!
National Science Education Standards* Addressed With This Monograph:

	IT'S A GAS!
Science as Inquiry	
Abilities necessary to do scientific inquiry	X
Understandings about scientific inquiry	X
Physical Science	
Properties of Matter	X
Transfer of Energy	X
Life Science	
Structure and Function in Living Systems	X
Populations and Ecosystems	X
Earth & Space Science	
Structure of the Earth System	X
Science and Technology	
Understandings About Science and Technology	X
Benefits and Consequences	X
Science in Personal & Social Perspective	
Personal Health	X
Natural Hazards	X
Risks and Benefits	X
History & nature of science	
Nature of science	X

* National Research Council, Content Standards, Grades 5-8.

What Is the USDA Forest Service?

The Forest Service is a part of the U.S. Department of Agriculture. It is made up of thousands of people who care for the Nation's forest land. The Forest Service manages over 150 national forests and almost 20 national grasslands. These are large areas of trees, streams, and grasslands. National forests are similar in some ways to national parks. Both are public lands, meaning that they are owned by the public and managed for the public's use and benefit. Both national forests and national parks provide clean water, homes for the animals that live in the wild, and places for people to do fun things in the outdoors. National forests also provide resources for people to use, such as trees for lumber, minerals, and plants used for medicines. Some people in the Forest Service are scientists, whose work is presented in the journal. Forest Service scientists work to solve problems and provide new information about natural resources so that we can make sure our natural environment is healthy—now and into the future.

http://www.fs.fed.us/

What Is the Cradle of Forestry Interpretive Association?

The Cradle of Forestry Interpretive Association (CFIA) is a nonprofit organization. It was founded in 1972 by a group of conservationists to help the Forest Service tell the story of forest conservation in America. The CFIA helps people better understand forests and the benefits of forest management.

http://www.cradleofforestry.com/interpretive_association/

United States Department of Agriculture

Forest Service
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Editorial Review Board

Every *Natural Inquirer* article is reviewed by a group of students. Student comments help to continually improve the *Natural Inquirer.* This is Mrs. Wilma Zapata's 5th grade class in San German, Puerto Rico.