Smithsonian
National Air and Space Museum

TEACHER GUIDE

Reflections on Earth

Biodiversity and Remote Sensing

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Conservation and Research Center

The Smithsonian Institution's
Monitoring and Assessment of Biodiversity
Program

Contents

How to Use This Guide

You and your students are invited to become explorers and scientists with *Reflections on Earth: Exploring Planet Earth from Space.* This exciting program from the Smithsonian Institution combines environmental studies, scientific research, and remote-sensing technology to help students develop a better understanding of the natural processes found on Earth. *Reflections on Earth* supports current science education guidelines that encourage student inquiry and active learning. The lessons and resources available through this program provide teachers with background information and activities to guide their students through investigations based on current research by Smithsonian scientists. Students also learn to use current research techniques and technologies, including remote-sensing data and images.

Remote sensing—the use of satellite images to study earth processes—is a powerful tool that allows environmental scientists and students to analyze changes on earth. The "satellite's-eye view" of our planet reveals patterns of color and brightness that tell of habitat growth and loss, soil and crop health, river systems threatened by pollution, and rainforests lost to burning. Remote sensing provides the only way to view entire ecosystems at a glance and it is an important tool in global efforts to better understand Earth's environments. Our Earth constantly is changing through a continuous cycle of natural processes and human influences—its map remains unfinished.

Biodiversity and Remote Sensing is part of a series of educational materials developed for the *Reflections on Earth* program. This guide consists of hands-on activities and resources for measuring and monitoring biodiversity on a local and regional scale. Students learn about biodiversity through an in-depth look at forest ecology. Just as a leaf is an avenue to studying a tree, a forest provides an avenue to understanding biodiversity. Conservation of forest biodiversity is a key component in maintaining the health of the planet. The activities included in the guide explore critical questions related to the scientific study of biodiversity.

Designed for students in Grades 5 through 10, this guide includes three activities:

- ★ Activity 1 takes one class period and is to be completed in your classroom.
- ★ Activity 2 takes one class period to prepare students, two full-day field trips (or the equivalent) to gather data, and one class period to summarize data.
- ★ Activity 3 takes two or three class periods.

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED IN THIS GUIDE

Science as Inquiry

- ★ Abilities necessary to do scientific inquiry
- ★ Understanding about scientific inquiry

Life Science

- ★ Populations and ecosystems
- ★ Diversity and adaptations of organisms
- ★ Interdependence of organisms

History and Nature of Science

- ★ Science as a human endeavor
- ★ Nature of science

Science and Technology

- ★ Understanding about science and technology
- ★ Abilities of technological design

Science in Personal and Social Perspectives

- ★ Science and technology in society
- ★ Natural resources
- ★ Science and technology in local, national, and global challenges

Biodiversity Assessment Model

TIME REQUIRED: ONE CLASS PERIOD **GRADE LEVEL:** 5 THROUGH 10

OVERVIEW

What is biodiversity, and how do scientists measure it? In this activity students define biodiversity and learn to measure and assess it.

OBJECTIVES

Students will conduct a simulated biodiversity assessment, calculate the relative abundance of species in a community, compare and contrast relative abundances in different communities, and draw bar graphs showing relative abundances.

BACKGROUND INFORMATION

The diversity of life on Earth is astounding. Nearly two million species of plants and animals have been identified, and, as incredible as it may seem, scientists estimate that there are more than ten million species. Unfortunately, many of these species will be extinct before they are identified and their contributions to the ecosystem understood. Although extinction is part of the natural process on Earth, there is reason to be concerned. Humans are changing the environment at an increasingly rapid rate and on an ever-greater scale. The resulting loss of habitat leads to the extinction of species. To better understand how the changing environment affects life on Earth, scientists are studying and monitoring changes in biodiversity.

MATERIALS

For each group of four students:

- ★ 1 copy of the Blackline Master: Three Study Sites cut apart
- ★ 3 small resealable sandwich bags

For each student:

- ★ A Comparison of Two Forest Plots
- ★ graph paper

Biological diversity, or ***biodiversity***, refers to the diversity of life on Earth with all its complexity. The concept includes all living organisms and their interactions with one another and with the environment. There are three levels of diversity: genetic diversity, species diversity, and ecosystem diversity.

Genetic diversity is the variety of genes that individual organisms express as traits or characteristics. Genetic diversity exists among species and within a given species. Greater genetic diversity exists between unrelated species, such as a ladybug and a rose, than between two related species, such as two species of salamander. However, genetic diversity exists even within a species where there can be various genes for a specific trait. For example, humans have genetic diversity in hair, eye, and skin color. Dogs have high genetic diversity in shape, size, and color. The more genetic diversity within a population, the better able the species is to survive changes in the environment. Species with low genetic diversity often have reproduction and health problems that can result in a decline of the species.

Species diversity is the variety of species that coexist within an ecosystem. Scientists measure species diversity by counting the number of species (species richness) and looking at patterns (relative abundance and dominance). By comparing species diversity at two different sites or by measuring how species diversity changes over time at a site, scientists can better understand biodiversity. Greater species diversity within an ecosystem generally means an increased ability to support change. Sometimes, even the loss of one species can disrupt an ecosystem.

Ecosystem diversity is the variety of ecosystems that exist within a region. Within a region, different sets of environmental conditions are capable of supporting different sets of species, which leads to the development of different ecosystems. Ecosystem diversity can be difficult to measure. The criteria used to define the boundaries of ecosystems are not always consistent, and, depending on the nature of the study, the scale can change. Since some species move between one ecosystem and another, the loss of one ecosystem may affect a second ecosystem. As humans expand agricultural lands, develop economic resources, and build housing, they alter ecosystems, so there is a resultant loss of habitat and the subsequent loss of species. As with the other forms of biodiversity, greater ecosystem diversity has its advantages. A region that contains more ecosystems is better able to support change.

Conservation of biodiversity is important for many reasons. Biodiversity stabilizes the environment and provides specific resources for human use. Ecosystems with greater species diversity recover faster from environmental stresses, such as drought and disease. The number of different genes found within a population of organisms is a form of insurance in a world that is constantly changing. This gene pool is important to the survival of species and to keeping potential resources available for human use. Many pharmaceuticals used today have been derived from tropical plants. Loss of tropical forests may mean the loss of plant species that have potential benefits for humans, as well as the ecosystem.

> A species is a group of individuals that can reproduce and whose offspring are also capable of reproduction.

Concerned about such losses, scientists conduct research to assess current biodiversity and monitor changes over time. Although there is no single measure of biodiversity, most discussions center on species diversity. The simplest measurement of species diversity is *species richness,* which is a count of the number of species in a given area. For example, a forest plot in a temperate climate may contain 34 tree species, while a tropical forest plot of the same size may contain over 200 tree species. However, when studying biodiversity, scientists are also concerned with patterns. They consider the *relative abundance* or *dominance* of each species. Relative abundance is the number of individuals of one species compared to the total number of individuals of all species. For example, one forest plot contains five different species of trees with each species almost equally represented. Another forest plot of the same size has seven different species, but 80 percent of the trees are of one species. Scientists would consider the first plot to have greater tree biodiversity, because the relative abundance of each species is more evenly distributed (see A Comparison of Two Forest Plots). Dominance is sometimes used to describe the same attributes as relative abundance. However, dominance can also refer to other measures, such as canopy cover or basal area (related to tree trunk diameter). For example, scientists will take the sum basal area of a particular tree and compare it to the basal area of all the trees in the plot.

> An ecosystem is a collection of species that coexist and interact within a given set of environmental conditions, such as temperature, pH, soil type, moisture, and sunlight.

Although it is possible to make a qualitative judgment of species diversity based on a quick review of the data in such a sample, the real world of research is far more complex, and science requires a quantitative assessment. Several methods are used to measure biodiversity. One of the simplest is the Shannon-Weiner Biodiversity Index.

The formula for the Shannon-Weiner Biodiversity Index is

$$H' = -[\sum (p_i)(\ln p_i)]$$

H' is the amount of diversity in an ecosystem.

p_i represents the proportion or relative abundance of each individual species to the total.
$\ln p_i$ represents the natural logarithm of p_i.

Using the Shannon-Weiner Biodiversity Index, Plot 1 is the most diverse, because it has a higher index (1.56) than Plot 2 (0.89). For a small sample, such as the one given above, advanced students may be able to use a graphing calculator or a spreadsheet to calculate the Shannon-Weiner Biodiversity Index for each plot. Typical study sites are far more complex and require hundreds of calculations to determine the Biodiversity Index. Because of this, scientists program computers to handle their calculations.

PREPARATION

Make one copy of the Three Study Sites blackline master for each student group. If possible, laminate the sheet. Cut the copies along the lines that separate each site and keep each study site separate. Cut out the squares. Each square represents an individual in the study site. The different icons represent different species. Place the squares for each study site in plastic bags and label them "Site 1," "Site 2," and "Site 3." Make one copy of A Comparison of Two Forest Plots blackline master for each student, or make an overhead transparency for the class.

PROCEDURES

1. Let students know that they will simulate a biodiversity assessment of three study sites. Ask students what they think biodiversity is and why scientists are concerned with it. Accept and record all answers. These will be discussed and refined after the activity. Let students know that in the simulation, each bag represents a different study site and each piece of paper in the bag represents an individual in the study site. Each icon indicates a different species. Review the definition of species.
2. Divide the students into groups of three or four. Let students know their assignment is to assess the biodiversity of each study site and to determine which site has the greatest biodiversity. (To do this, students first will have to develop a definition of biodiversity and then measure the diversity of each study site against their definition.)
3. Distribute three bags (one of each study site) to each group. Ask students to work in their groups to determine which site has the greatest diversity.
4. Have students share their findings and defend their selections. Site 1 and Site 3 have individuals from the three different species, while Site 2 has only one species. Most students will eliminate Site 2. However, it is more difficult to determine whether Site 1 or 3 is more diverse. Let students know that scientists are concerned both with the number of species found in a community *and* the number of individuals of each species. In Site 3, the population is more evenly divided among the three species. Scientists would consider Site 3 to have greater species diversity.
5. Let students know that most discussion about biodiversity centers on species diversity. When determining species diversity, scientists consider two aspects of a population: species richness and relative abundance. *Species richness* is the number of species, while *relative abundance* is the number of individuals of a given species compared with the total number of individuals.
6. Display or distribute A Comparison of Two Forest Plots and a sheet of graph paper. Have students determine species richness for each plot, calculate and graph relative abundance for each species, and determine which plot has the greatest biodiversity.
7. Discuss the student work and graphs. Although Plot 2 has greater species richness, scientists would consider Plot 1 to have greater species diversity. The relative abundance of each species is more evenly distributed. Let students know that the real world of research is more complex, and science requires a quantitative assessment. Scientists use several statistical methods to calculate a biodiversity index.
8. If your students are capable of handling the mathematics, have them calculate the Shannon-Weiner Biodiversity Index for each of the plots. Otherwise, tell them that the Shannon-Weiner Biodiversity Index for Plot 1 is 1.56, while Plot 2 has a lower index, 0.89. Thus, Plot 1 has greater biodiversity.

REFLECTION AND DISCUSSION

1. Display the students' original definitions for biodiversity. Ask them to refine the definition based on their work on this activity. Let students know that although species diversity is the most common measure of biodiversity, scientists also measure genetic diversity and ecosystem diversity.
2. Ask students why an ecosystem with a greater diversity of species might be healthier than an ecosystem with only a few species. (The larger the number of species, the more likely the habitat can recover from a change in conditions, such as disease, drought, or fire.)

1. *Which plot has greater species richness?* ____________________________

2. *Calculate the relative abundance of each species and enter in the tables below.*

$$\text{Relative abundance} = \frac{\text{number of individuals of a species}}{\text{total number of individuals}}$$

3. *Make a bar graph for each plot showing the relative abundance of each species.*
   x-axis, list species (oak, hickory, etc.)
   y-axis, list relative abundance (0, 0.1, 0.2, 0.3…1.0)

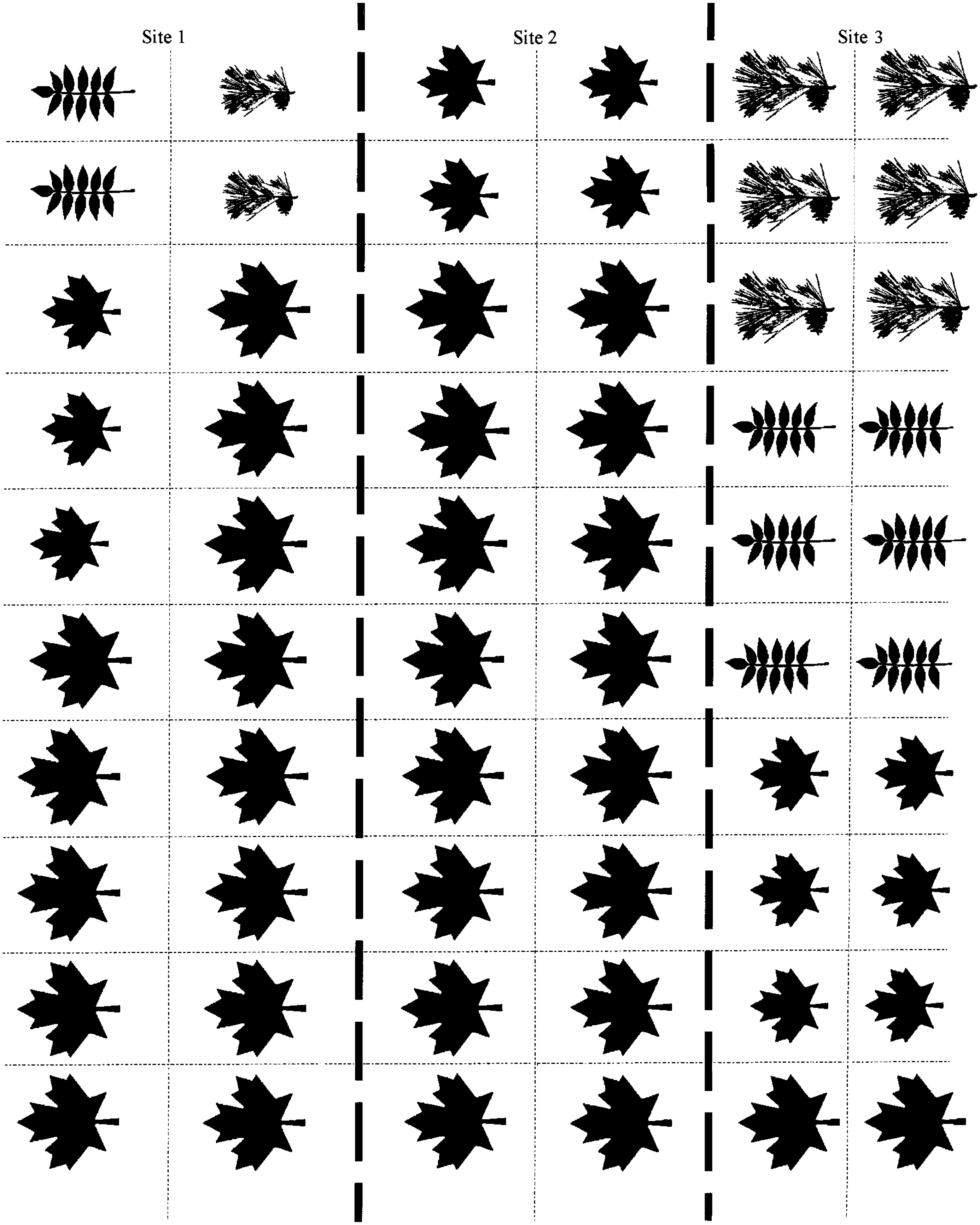
4. *Which plot has greater species diversity?* ____________________________

Plot 1

Tree species	Oak	Hickory	Dogwood	Sassafras	White Pine	Total
Individual Trees	26	32	45	18	39	160
Relative Abundance						---

Plot 2

Tree species	Oak	Hickory	Dogwood	Sassafras	White pine	Beech	Sycamore	Total
Individual Trees	1	3	7	4	2	80	2	99
Relative Abundance								---


Site 1
Site 2
Site 3

Activity 2

Forest Biodiversity Assessment

TIME REQUIRED: ONE CLASS PERIOD TO PREPARE STUDENTS, TWO FULL-DAY FIELD TRIPS (OR THE EQUIVALENT), AND ONE CLASS PERIOD TO SUMMARIZE DATA

GRADE LEVEL: 5 THROUGH 10

MATERIALS

For class:

- ★ 1 to 2 20 m x 20 m wooded plots, divided into four 10 m x 10 m quadrats
- ★ 2 to 4 30-m measuring tapes
- ★ 9 plastic or wooden stakes, each 10" to 12" long
- ★ string to mark plot boundaries

For each team of up to four students assigned to a 10 m x 10 m quadrat:

- ★ chalk
- ★ 2 to 3 clipboards
- ★ 50 to 100 numbered, aluminum, or plastic tree tags*
- ★ 3" aluminum nails, one for each tag or bell wire to fasten tags
- ★ 1 hammer
- ★ tape measure or DBH tape*
- ★ field guide to trees
- ★ binoculars (optional)
- ★ flagging tape (colored, plastic, nonadhesive tape)
- ★ 1 copy of Blackline Master: Quadrat Grid Map
- ★ 2 to 3 copies of Blackline Master: Tree Inventory Data Sheet

For each student:

- ★ 1 copy of Blackline Master: Tree Inventory Instructions

*Tree tags and DBH tape can be purchased from forestry supply companies, such as Ben Meadows Company (www.benmeadows.com) or Forestry Suppliers, Inc. (www.forestry-suppliers.com).

OVERVIEW

How do scientists assess biodiversity in a forest? This activity is based on the protocols established by Smithsonian scientists to map and inventory the trees in a forest. Such surveys record the number and types of organisms that live in a forest and help us to understand their requirements for survival.

OBJECTIVES

Students will observe, measure, and identify trees in a biodiversity monitoring plot, find coordinates for the trees in the plot, and prepare a map. They will then calculate the relative abundance of tree species.

BACKGROUND INFORMATION

Forests are a good place to begin the study of biodiversity. Trees form the template upon which other species rest. To understand the patterns of wildflowers, birds, insects, or small mammals in a region, scientists often start by mapping the pattern of trees. Tree species are a good predictor of the animal and insect species found in a specific area. Trees also are closely tied to the *abiotic* (nonliving) conditions of the site, such as temperature and rainfall. In addition to providing valuable information about the life forms and environmental conditions of an area, trees are relatively easy to study. For the most part, tree species in temperate and boreal forests are easy to identify, and trees are easy to measure. Forests, as well as other vegetation, form the basis for large-scale studies monitoring biodiversity. Scientists use remote-sensing technology in conjunction with field studies and other data to identify forest types and to monitor changes to forests. Forests provide a variety of habitats for plants, animals, and microorganisms. The loss of forests, their fragmentation, and changes in their composition result in the loss of habitat. This, in turn, leads to the loss of species. Because of the close link between forests and the life forms they support, conservation of forest habitat is crucial in sustaining biodiversity.

Although scientists agree that conservation of biodiversity is critical to the health of the planet, they are still working on the best methods to achieve this goal. To determine which areas should be protected and how best to protect them, scientists have developed protocols to measure and monitor forested habitats worldwide. Smithsonian scientists have developed a biodiversity plot system that calls for a 100 m x 100 m plot, divided into 25 quadrats, each measuring 20 m x 20 m (see Figure 1). This grid system allows scientists to accurately describe the position of organisms within the study area. Since the plot size is consistent, scientists easily can compare plots from different locations.

Activity 2 is modeled after the protocols developed by Smithsonian scientists. However, the student plot is comparable to one quadrat in a Smithsonian Forest Biodiversity Plot. To make it more manageable, student plots will be 20 m x 20 m, divided into four quadrats measuring 10 m x 10 m each. Student plots can be compared with others' since the plot size will remain consistent.

In the biodiversity plot, students will complete the following:

- ★ Tag each tree with a unique identification number
- ★ Measure each tree's diameter at breast height (DBH)
- ★ Map the location of the trees
- ★ Identify the tree species
- ★ Calculate the relative abundance of each tree species

PREPARATION

1. Identify a 20 m x 20 m plot in a local forest, and get permission for you and your students to work on the site. For a large class, two 20 m x 20 m plots may be required. When selecting the plot, consider that you may want to expand the plot in subsequent years. Lay out the plot as indicated in Figure 2 (the small black squares represent stakes). Mark the four corners of the plot with stakes. Select one corner of the plot to be the origin of the coordinate system, and mark it with a piece of flagging tape or brightly colored material.

   Connect the stakes with string to mark the boundaries of the plot. Now add stakes in the middle of each side and in the middle of the plot to create the four quadrats. Connect these stakes with string. The plot is now prepared.

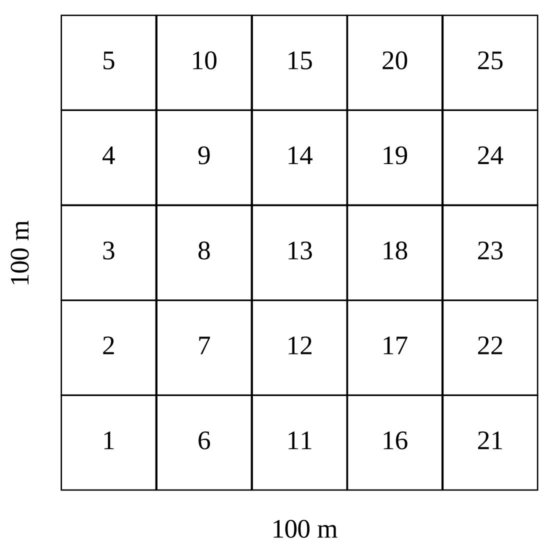


Figure 1: A 1-ha Biodiversity Monitoring Plot

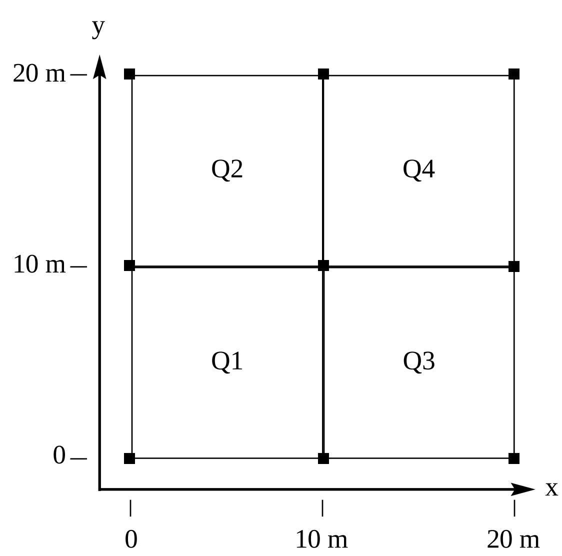


Figure 2: A 20 m x 20 m Student Biodiversity Monitoring Plot divided into four quadrats.

Students will work in teams of up to four students for each quadrat. You will need one 50-minute class period to prepare students for the field trip and at least two days in the field to inventory, identify, and map trees. If your schedule permits, plan subsequent field trips where students can collect additional data, such as slope and aspect (the compass direction the slope faces), canopy cover, ground cover, soil properties, and plant, insect, bird, and small mammal populations. One additional class period is needed to summarize the data findings.

2. Review the Blackline Master: Tree Inventory Instructions. Refine and elaborate the instructions depending on the nature of your plot and the equipment you have available. If you plan to use the plot to measure change in future years, you will want to make the tags as permanent as possible. Use prenumbered aluminum tags, if possible. Have students drive the nails into the tree with the heads pointing down, so the tags will hang away from the bark. Drive the nails just deep enough, so they will not come out when pulled. If you do not want to nail the tags, fasten them loosely around the trunk or on a low-hanging branch near the trunk with twisted bell wire (plastic-coated, electric wire). If it creates a problem, the trees do not have to be marked for the students to complete the inventory.

   Students will be divided into four teams to collect field data, one for each quadrat. However, to speed up the process and to allow everyone on the team to participate team members may specialize, with some students tagging and measuring and others identifying the trees. Students in the same quadrat can record their data on separate sheets and compile it later.

PROCEDURE

1. Begin with a discussion. Ask students what the term biodiversity means and why biodiversity is important. Tell students they will conduct a biodiversity assessment of a forest plot. Ask students to predict the kinds of plants, animals, insects, trees, and microorganisms they would expect to find in the forest. Ask the students to brainstorm methods that can be used to measure the biodiversity of a forest. Mention that one method is to take an inventory of the plants and animals in that area.

2. Familiarize students with the field procedures. Hand out Blackline Master: Tree Inventory Instructions, and review the procedures and equipment for the tree inventory.

★ Review the Biodiversity Monitoring Plot in item 1. Describe the quadrats and coordinate system.

★ Give procedures for tagging the trees, as described in item 2. Review the materials and equipment students will be using.

★ Demonstrate how to measure DBH (diameter at breast height). Students should hold the tape around the trunk of the tree 1.3 m from the ground. If using DBH tape, the measure will be given as the diameter. If you are using a tape measure, students will have to convert from circumference to diameter (circumference $\div \pi$ = diameter). You may want to have students record the circumference in the field and convert to diameter back in the classroom.

★ Explain how to determine the x- and y-coordinates for trees in the biodiversity plot. The coordinate system applies to the entire biodiversity plot. Each quadrat will have a unique set of coordinates.

★ Review how to identify tree species and how to use the field guides. If leaves are out of reach and students cannot collect a leaf sample, have them examine the leaves with binoculars, if possible.

3. Prepare students to work in teams. Divide students into four teams and assign each team to a quadrat. Have student teams plan for fieldwork by discussing how they will divide assignments, share equipment, and complete the inventory.

4. Conduct the field study. Have students place the two 30-m tapes so they cross in the center of the plot with 0 m placed on the x- and y-axes, as indicated on the Biodiversity Plot drawing on the student instruction sheet. Although the x- and y-coordinates are typically laid out from the origin, placing the measuring tape across the center of the plot makes it easier to determine the coordinates from each of the quadrats. Review the coordinate system. Have students work in teams to complete the Blackline Master: Tree Inventory Data Sheet.

5. As students work in the field, confirm that they are using the equipment properly and are making correct measurements and identifications. Before leaving the plot, have students review their coordinates to make sure they fall within the proper quadrat. For example, quadrat 1 coordinates should be between 0,0 and 10,10.

Students measuring tree coordinates

6. Back in the classroom, have students compile their data. Determine the species richness. How many tree species were found on the biodiversity plot? Determine the relative abundance of each species. How many trees are there of each species? Calculate the relative abundance of each species.

$$\text{Relative Abundance} = \frac{\text{number of individuals of a species}}{\text{total number of individuals of all species}}$$

7. Have students compare their biodiversity plot to the two sample plots in Activity 1. What can they say about the species diversity among the different plots?
8. Have students create a quadrat grid map on chart paper. Have each team label the x/y coordinates on the quadrat grid map. Students then plot each tree on the map using the tree tag number.
9. Display the completed quadrat grid maps and have students look for patterns. Suggest that they look for species growing in clumps or at some regular or minimum distance from each other. Have the students compare the mean DBH measurements of each species. By creating maps of each tree species on separate sheets of flip-chart paper, students can compare distributions and look for patterns. Patterns are more easily seen in larger areas, such as a hectare (100 m^2) than in a quadrat (20 m^2).

REFLECTION AND DISCUSSION

1. Ask students how a tree census contributes to understanding biodiversity in a forest. (Measurements and analysis of tree species help scientists draw conclusions about the overall health of the forest which contributes to the biodiversity of the area.)
2. Ask students to describe signs, if any, indicating that the forest is biologically diverse?
3. Ask students how the forest might change in five years, in fifty years, in one hundred years. How will the forest differ from the way it appears now?

EXTENSIONS

1. Have students perform the same kind of counting, identification, and mapping activity for different species, such as wildflowers, insects, or amphibians. Create a class identification key for species found within the biodiversity plot.
2. Have students record physical characteristics of their quadrat, such as temperature, precipitation, amount of sunlight, soil type, pH, or topography.
3. Use the data collected on your biodiversity plot as a basis for spreadsheet or graphing calculator exercises. Students can use a spreadsheet program to compile and store the data and create charts and graphs. Scatter graphs can be used as maps to visualize the plot using the tree coordinates. Work with a math teacher at your school to use the data for graphing calculator exercises or statistical analysis such as distribution, proportion, mean and variance.
4. Make tree mapping and identification an annual project so that students can observe changes over time in the study area's tree cover. Observe and record seasonal changes and patterns.
5. If you have set up two or more 20 x 20 m plots, or if you know another school that has set up such a plot, have students compare and contrast the biodiversity of each one.

Activity 2 Blackline Master:
Tree Inventory Data Sheet

Quadrat #______________________________ Date ____________________________________

Team Members ____

Tree Tag #	Species Common Name Scientific Name	DBH	Coordinates		Status	Notes
			x	y		

Status: AS, alive standing; AL, alive leaning; AB, alive broken; AF, alive fallen;
DS, dead standing; DL, dead leaning; DB, dead broken; DF, dead fallen

Date________________________________ Assigned Quadrat____________________________

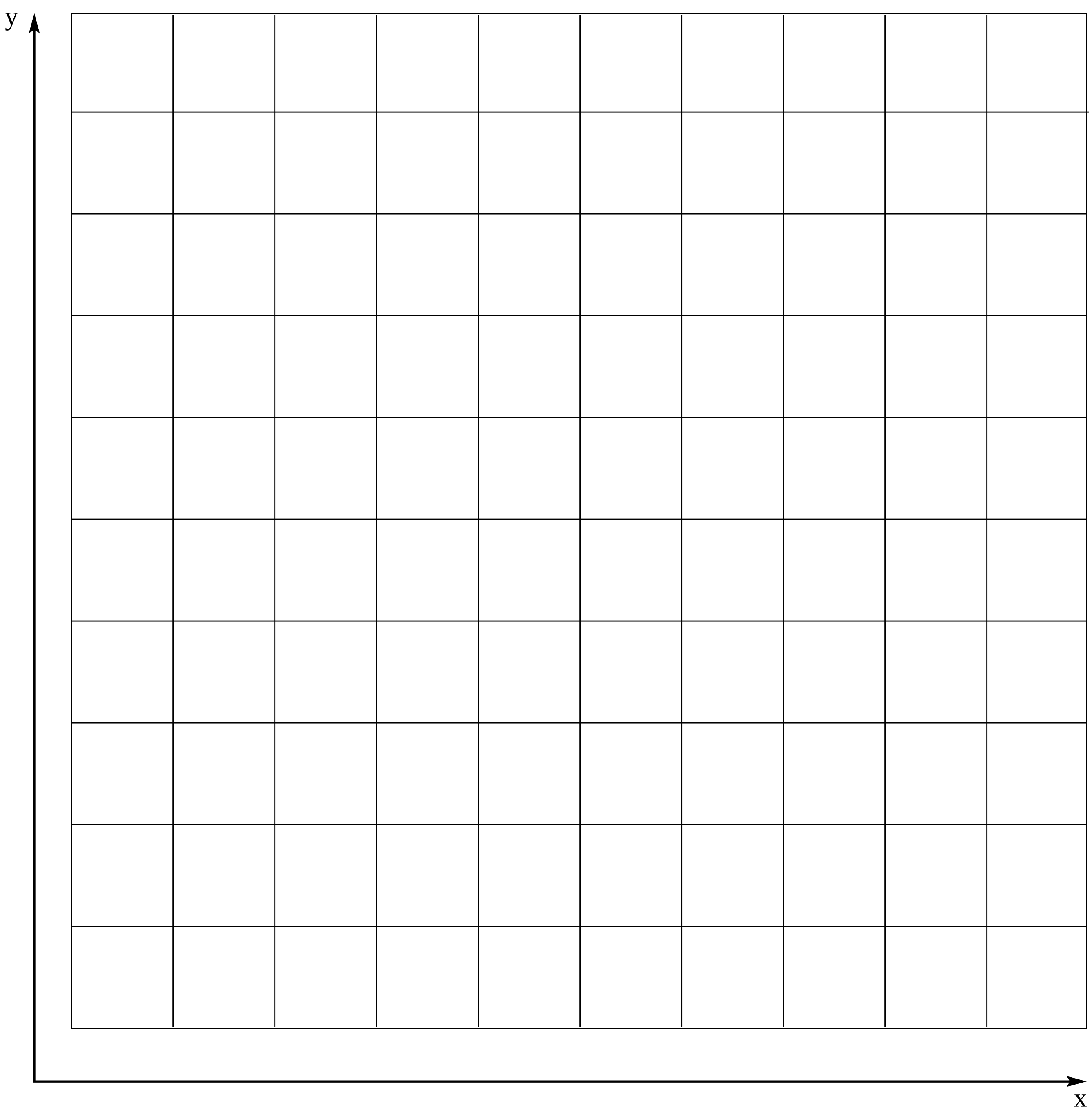
Team Members:____

Circle x and y coordinates you are using based on quadrat:

Q1 x=1–10, y=1–10   Q3 x=10–20, y=1–10

Q2 x=1–10, y=10–20   Q4 x=10–20, y=10–20

Write the coordinate numbers for your quadrat on the map below. Each square is 1 m x 1 m.



Land Cover Mapping

TIME REQUIRED: TWO TO THREE CLASS PERIODS **GRADE LEVEL:** 5 THROUGH 10

OVERVIEW

Thinking more globally, how do scientists assess biodiversity for large regions? In this activity, students emulate scientists by using a satellite image to determine different land cover types and create a land cover map of Front Royal, Virginia.

OBJECTIVES

Students will be introduced to remote-sensing techniques and their applications in monitoring forest biodiversity. Students will visually interpret a satellite image (as opposed to spectral reflectance analysis) and classify land cover types. Typically this is the first step in image interpretation. Then, in a simulated exercise, students will serve as scientific advisors to a conservation organization. They will use the image and a topographic map to create a land cover map which they will use, along with field data, to determine optimal locations for a biodiversity study site.

BACKGROUND INFORMATION

Scientists now apply remote-sensing techniques to the study of biodiversity. By using images produced from satellite data, they identify and map land cover over large regions of the Earth. *Land cover* refers to the type of features present on the surface of the Earth. This can be human-made structures, types of vegetation, or other natural features such as water. Such maps provide detailed information about the location and extent of vegetation types. Forests are especially important for the study of biodiversity on a global scale, as they cover nearly one-third of the world's land area and provide habitat for many diverse species. As scientists refine their use of satellite data to identify forest types, they also increase their capacity to monitor and assess biodiversity at both regional and global levels.

Remote sensing refers to different techniques for collecting data about a surface or object from a distance. Most remote-sensing observations measure the degree to which the Sun's energy, in a given electromagnetic wavelength, is reflected from the surface. Remote-sensing observation systems usually collect data in the form of images built up from hundreds to millions of picture elements or *pixels*. Different surfaces—water, rock, vegetation—have at least a slightly different response to electromagnetic radiation, which allows us to use satellite data to identify land cover.

Such knowledge forms the basis for many land management and planning decisions, including those affecting conservation of biodiversity. For example, the U.S. Geological Survey's National Gap Analysis Program (GAP) uses satellite imagery and geographic information systems (GIS) to analyze biodiversity on both state and national levels and to identify gaps in management efforts. The program classifies land ownership and land use, maps the distribution of vegetation types, and predicts the distribution of vertebrate species by associating their distributions with the current habitat and vegetation types. This information provides an objective basis for decisions related to the management of biological resources at local, state, and national levels.

Land cover maps allow scientists to visually analyze the location and extent of different land cover types (see Figure 3). By using such maps to estimate the area and

MATERIALS

For each group:

- ★ copies of blackline masters:
  - Land Cover Grid (transparency)
  - Ground Truth Field Data
  - Habitat Information
- ★ satellite image
- ★ topographic map
- ★ blank transparency (or tracing paper)
- ★ markers (or colored pencils)

Optional:

- ★ transparency of Reflected Energy graph distribution of specific ecosystems across large regions, they can predict which animal and plant species will be found there. Also, land cover maps provide baseline measurements that allow researchers to study changes over time and to discover what impact such changes have on biodiversity. Additionally, land cover maps are useful for determining habitat fragmentation, now considered as the leading cause for loss of global biological diversity (Wilson, 1992). Accurate land cover maps enable us to identify and preserve areas that have the greatest potential contribution to long-term conservation of biodiversity, and they target sites that will provide the most useful information for scientists and policymakers.

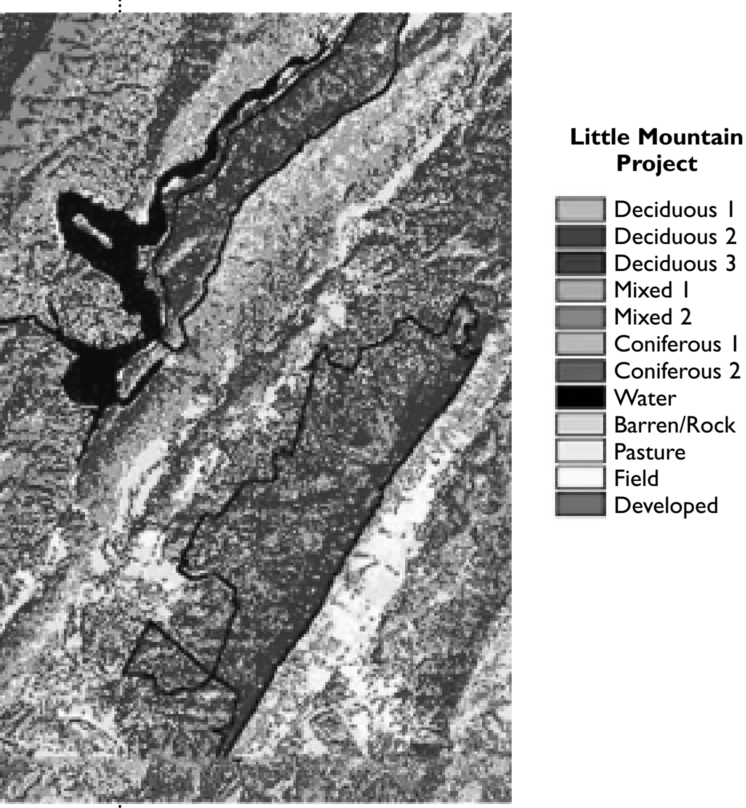


Figure 3: Land cover map of a forest management unit on Little Mountain in the George Washington National Forest in Virginia. (Source: Smithsonian National Zoological Park's Conservation and Research Center)

According to the National Aeronautics and Space Administration's (NASA's) education module, "Studying Earth's Environment from Space," land cover classification using remote sensing is based on the assumption that different types of land cover have distinct reflectance properties. The unique spectral properties of a land cover class are derived from a number of factors, including canopy geometry, leaf densities, colors, optical properties and moisture content, shadows, transpiration rates, and the properties of nonvegetated areas. Defined by the wavelength bands collected for the image analysis, these attributes are known as the *class spectral signature*. Classification of land cover types using spectral reflectance properties requires the use of a computer to handle the statistical calculations carried out on each pixel of an image.

Although remote-sensing techniques hold great promise for extending our understanding of biodiversity to a global level, scientists using satellite data to identify forests and other vegetation only now are able to reliably achieve the level of detail necessary for biodiversity studies. Interpretation of vegetation is complicated by seasonal variations, environmental factors, and health of the vegetation. Transitional zones and climatic gradients make the task even more difficult. However, as remote-sensing instruments have become increasingly more sophisticated, scientists have been able to standardize methods of classification. As they compare field data to satellite imagery, they also use additional environmental data to aid interpretation. These combined efforts can only improve our understanding of biodiversity and minimize future biodiversity loss.

About the Image. Acquired by Landsat Thematic Mapper (TM) in November of 1992, this satellite image shows the area around Front Royal, Virginia, located 70 mi west of Washington, D.C. The area covered by the image is approximately 378 km^2. In a digital image, a pixel is the single smallest sample of data. The *spatial resolution*, or pixel size of this image, is 30 m. For a single wavelength band in the electromagnetic spectrum, the pixels form a two-dimensional grid, where the value of each pixel indicates the brightness for that point on the ground. In Landsat data, this brightness value is specified by a number between 0 and 255.

This image is a composite made from three wavelength bands, which include the near infrared and the red and green portions of the visible spectrum. Green plants reflect strongly in the infrared, so this wavelength band is used for vegetation studies. Our eyes can only see combinations of three colors—red, green, and blue. These colors have been assigned to the wavelength bands, creating a false-color image with red assigned to reflected infrared, green to reflected visible red, and blue to reflected green (see Figure 4).

GUIDE TO INTERPRETING COLORS ON THE SATELLITE IMAGE

Red: healthy vegetation

Pink: less densely vegetated areas or, possibly, less healthy vegetation

Tan, brown, green with patches of red: forests (darker shades are shadows on the mountains)

Dark blue: rivers, lakes, streams or reservoirs

Light blue and gray: urban areas, cities, towns, buildings, concrete and other human-made features

White: bare land, fields or soil with sparse or no vegetation. (There are no clouds or snow in this image.)

PREPARATION

Students will benefit from a basic understanding of remote-sensing technology as presented in the "Reflections on Earth" teaching poster available from the Smithsonian's National Air and Space Museum and web page.

Divide the students into groups. Choose the group size so that there is one satellite image for each group, or make additional color copies of the image. Photocopy the Blackline Master: Land Cover Grid onto an overhead transparency, one for each group. Copy the Blackline Masters: Ground Truth Field Data and Habitat Information, one for each group.

PROCEDURE

1. Ask the students to imagine that they are scientists who have been asked by an international conservation organization to recommend a location for a biodiversity study site. You can mention that Smithsonian scientists often work with governments and other organizations to establish biodiversity preserves and study sites for a given region, as your students will in this simulation. Ask students what information they would need about the region to decide which site would be most appropriate. Ask them where they would obtain the information. Give them five minutes to brainstorm ideas in their group, and then have them share their ideas with the class (for example, topographic maps, aerial photos, satellite images, field research on the type of terrain, climate studies, and so forth).
2. Distribute one copy of the color satellite image found at the end of this guide to each group of students. Let students know that this image is a false-color image from Landsat TM. The region is Front Royal, Virginia, 70 mi west of Washington, D.C. The resolution is 30 m x 30 m and the scale is 1 cm = 1 km. Give groups five to ten minutes to see what they can identify in the image. Discuss their findings. Could they identify key features, such as water, forest, agricultural and urban areas? What color corresponds with each feature? Go over the color chart from the Background Information. Mention that geometric shapes usually

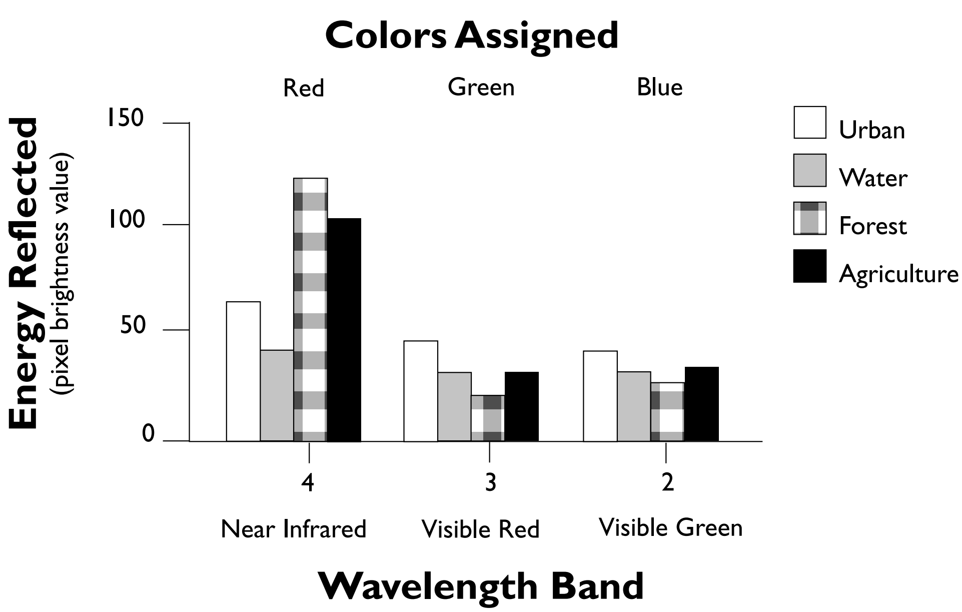


Figure 4: Energy reflected in three wavelength bands

indicate human-made areas, such as agricultural fields, airports, and paved surfaces. Inform students that they have begun the initial stage of image interpretation.

For more advanced students, make a transparency of the reflected energy graph on page 31 (Figure 4). Explain that the bar graphs show how much light is reflected in each wavelength band. The brightness of each pixel in a satellite image is specified by a number between 0 and 255. This value is represented on the y-axis. Ask students to compare and contrast how the four types of land cover reflect light. Review the colors that have been assigned to each band to make the image. Using the satellite image, examine the four spectra from locations marked by the letters *A*, *B, C* and *D*. These locations include forest, water, urban areas, and agricultural lands. Have students review the graph of spectral radiance for these four land covers, so they can see that vegetation (forest and agriculture) has a strong return in the "Near Infrared," which appears as red on the image. Therefore, red areas are most likely forest or agricultural fields. Since this image was taken in the fall, deciduous trees have lost their leaves and these areas are brown, tan, and green instead of bright red. Ask them to determine the locations of regions on this image that have the characteristics of water, forest, agricultural, and urban lands.

3. Explain that researchers confirm their interpretation of satellite images with *ground truth studies*, when possible. To conduct ground truth studies, scientists travel to selected locations in the area of the image to make field observations. Since the students will not be traveling to Front Royal, Virginia, to verify this image, field data are provided by the Blackline Master: Ground Truth Field Data. Students will use the field data to identify and make inferences about areas in the image that are similar in appearance to the corresponding letters.

4. Let the students know that they will work in groups to simulate the work of scientists who advise conservation organizations. Using the satellite image, the topographic map, field data, and habitat information, each group will complete the following tasks:

- ★ Prepare a land cover map.
- ★ Calculate the relative area for each type of land cover.
- ★ Select an area of at least 1 km^2 to recommend for a biodiversity study site.

5. Distribute all materials to each group. Explain that each group will make a land cover map of the satellite image by placing the blank transparency over the satellite image and outlining the boundaries of areas that appear different. (Tracing paper can be substituted for transparencies.) Students should classify the different land cover types. Areas with the same appearance and characteristics should be classified as the same land cover type and coded with same color or symbol. See Figure 5. Land cover can include urban areas, forests, agricultural lands, and water. Using the topographic map as a reference, add other features that relate to the land cover, such as rivers, roads, or mountains.

6. Students should supply a legend for their map.

Figure 5: Sample student land cover map

7. Have students use the transparency of the Land Cover Grid to measure the relative area of each land cover type. Explain that they can lay the grid over their map and simply count the number of squares in each kind of land cover. If possible, they should keep track of fractions of squares. The number of squares for a given land cover type divided by the total number of squares gives the relative area for that land cover type (for example: 40 ÷ 391 = 0.10 or 10 percent).

8. In preparation for selecting a biodiversity study site, have students review the land cover map, field data, and habitat information. Before selecting the site, students should consider what they plan to study. Have them determine which type of species they will census: mammals, birds, amphibians, insects, vegetation, or others. Will they be looking at changes over time or will they compare two different sites? Do they want to study the effects on species that land cover might have (such as nearby urban areas, fragmented or separated forest patches, and edges near agriculture)? Once they have determined the nature of their study, have them select and outline their location(s) on their land cover map. Since the hypothetical conservation organization has limited funding, students may choose one or two sites, but their total area should not exceed 2 km^2. Each group should prepare and deliver a presentation describing the location(s) they recommend, the type of study to be conducted, and their reasons for choosing that area.

Students creating a land cover map.

REFLECTION AND DISCUSSION

1. Ask students to discuss the relationship between land cover and biodiversity. (Land cover—especially vegetation—provides information about habitat, which allows scientists to predict the species that will be found there.)
2. Ask why ground validation is so important for interpreting satellite imagery. (This confirms the interpretation of satellite images for specific sites and allows scientists to expand or extrapolate field data to larger regions.)
3. Why it is important to study land cover? (There are many reasons why the study of land cover is crucial. For example, it is important for improving agriculture, for maintaining the water supply, for maintaining the balance between protecting forests and harvesting trees, and for monitoring biodiversity.)
4. Ask students if they think that their school biodiversity plot would be visible on a satellite image. (It depends on the resolution of the image. Each pixel in a Landsat TM image has a resolution of 30 m. A 1-ha plot (100 m x 100 m) would be equivalent to approximately 9 pixels (a square of 3 pixels by 3 pixels). School biodiversity plots are only 20 m^2.)
5. Ask students what factors might affect the use of satellite images. (Cloud cover, for example, can reduce the detail obtained from a Landsat image.)

EXTENSIONS

1. Repeat the above activity with a satellite image of your school site, (which should be available from the USGS web site) and a local topographic map (available from camping and outdoor equipment stores). After students have finished the activity, ask what kind of animal life they might expect to find, and why. What steps could they take to help preserve or enhance habitat for the local plants and animals? Ask them to compare and contrast their local area to that of Front Royal, Virginia. Now that students know more about the biodiversity in their area, how would they find out about biodiversity in other regions of the world?
2. Discuss the issue of working with images of the same area acquired at different times of the year (for example, spring and fall). The image used in this activity was taken in November. How would an image of the same area acquired in the spring or summer affect the interpretation? (Many features change with a seasonal regularity.)

CURRICULUM CONNECTIONS

- ★ Have students write a story about a team that traveled to a remote place to do ground truthing.
- ★ Have the students research a remote location and draw a map of its ground cover.
- ★ Have students research a land-use issue in their community.

The following field data corresponds to the letters found on the satellite image. Use this information to identify and make inferences about areas in the image that are similar in appearance to these points.

AREA A	AREA B
Biodiversity plot tree data (Forest Type: deciduous) **Tree species occurring in study plot:** Oak, Hickory, Blackgum, Sassafras, Witch hazel, American beech, Eastern white pine, Flowering dogwood, American hornbeam, Tulip tree, Red maple, Red elm, Black locust, White ash, Pawpaw	**Water resources:** Shenandoah River South Fork North Fork Sewage disposal tanks Various ponds
AREA C	**AREA D**
City of Front Royal: Houses Route 522 Highway 66 Happy Creek Road K-mart Parking lot Power line	**Agriculture:** Fields Pasture Small vineyard Stockpiled fescue grass Fields of winter wheat Small forested areas

Different land cover types can influence biological diversity in an area. Given the following information on four types of land cover that can be seen in the satellite image, determine where your team will locate the biodiversity preserve. Choose the location that would have the most biodiversity. (It does not need to be one of the labeled areas on the image.)

URBAN

In this urban area, most land cover consists of impervious surfaces such as concrete and asphalt. There are a few residential gardens and vacant areas, isolated from each other, that provide habitat for some wildlife species. This isolation can effect the movement of certain species. There are several community parks that are primarily lawn with a few mature trees. There is a higher level of human population as well as air and water pollution. This land cover appears light blue on the image. Bare surfaces surrounding the city of Front Royal appear white and light pink.

AGRICULTURE

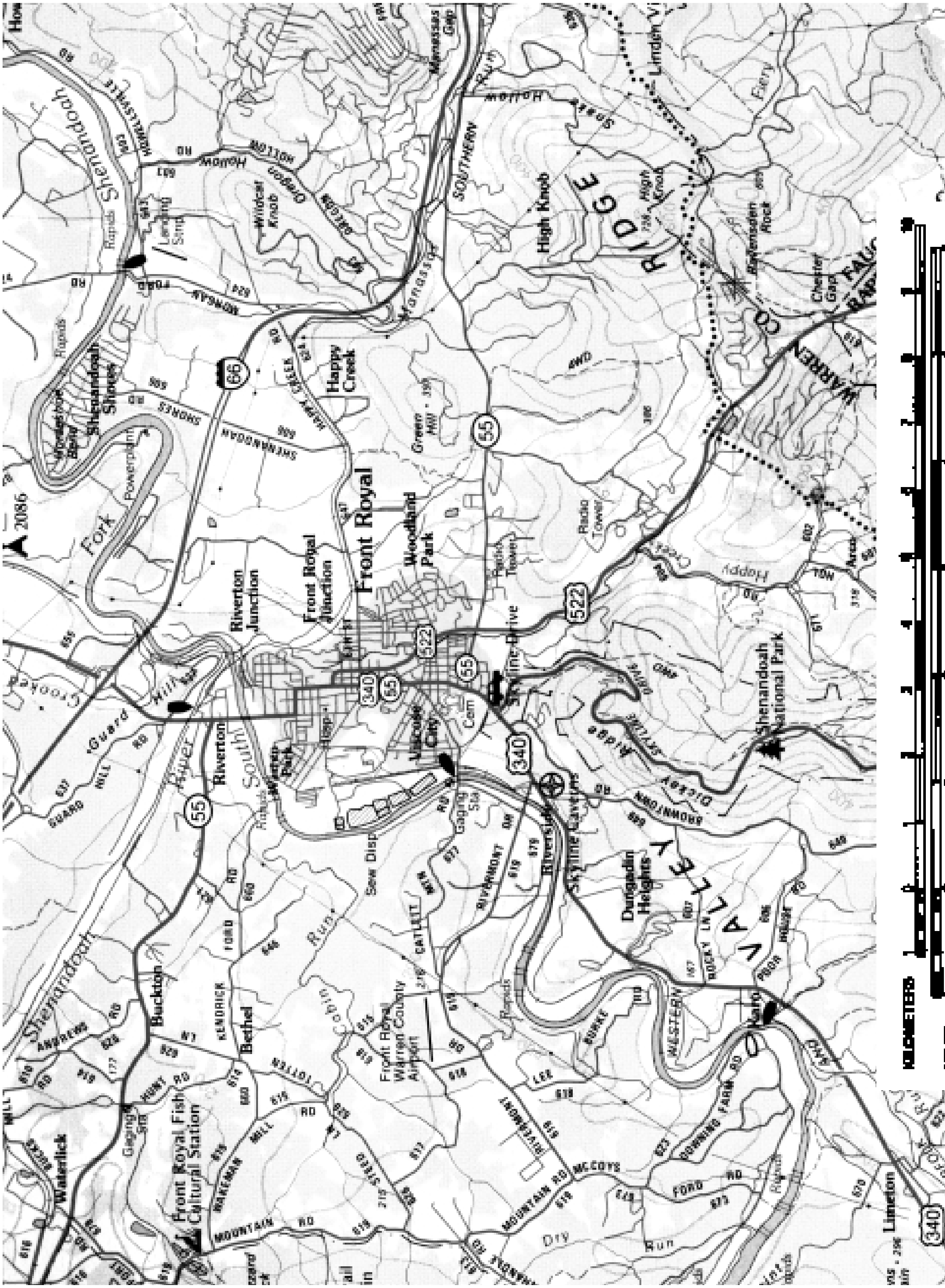
Typically, agricultural areas are comprised of a variety of managed ecosystems. The predominant pattern of agricultural development consists of fields of one particular crop plant that are occasionally treated with pesticides to prevent plant loss. A variety of domestic animals are present. While some wild species of plants and animals live among the crops, most of the wildlife depends on fragments of meadows, hedgerows, and woodlands surrounding the fields. For these species, the habitat often consists of small patches scattered throughout the landscape. This land cover appears red on the image. It is readily apparent east of the Shenandoah River and has a more square or rectangular shape.

FOREST

The mixed deciduous forest seen in the image contains multiple layers that provide habitat for many different species: A top level consists of tree canopy cover, a midstory of younger trees, an understory of smaller trees and shrubs, a ground layer of herbaceous plants (wild flowers and ferns), and a surface layer of lichens and mosses. These conditions provide abundant food and shelter for a variety of wildlife species. In this satellite image, forests appear brown and tan with some patches of red.

FIELDS

This land surface has exposed areas due to relatively recent clearing. Characteristic plants found in fields are mainly herbaceous plants such as grasses and wild flowers. Some tree saplings and shrubs may be present. Animals often visit fields, even though they do not live there year-round. They may come only at certain times of the day to graze or in seasons when food in other habitats is scarce. Species living in fields have had to adapt to extreme temperatures and winds. White and light pink areas on the image indicate fields.


Front Royal
Riverton
Riverton Junction
Front Royal Junction
Woodland Park
Happy Creek
High Knob
Shenandoah National Park
Skyline Drive
Skyline Caverns
Dungadin Heights
Buckton
Bethel
Limeton
Waterlick
Front Royal Fish Cultural Station
Front Royal Warren County Airport
Shenandoah Shores
KILOMETERS
MILES

Resources

BOOKS

Strain, P., and Engle, F. *Looking at Earth* (Atlanta, Ga.: Turner Publishing, Inc., 1992)

Wilson, Edward O. *The Diversity of Life* (New York: W.W. Norton & Company, Inc., 1992)

RELATED TEACHER GUIDES

Reflections on Earth Teaching Poster (2000) Smithsonian, National Air and Space Museum, Washington, D.C. 20560-0305

Windows on the Wild (1994) World Wildlife Fund, 1250 24th St., NW, Washington, D.C. 20037

The Changing Forest: Forest Ecology (1996) Project Learning Tree, American Forest Foundation, Suite 780, 1111 19th St., NW, Washington, D.C. 20036

Ground Truth Studies Teacher Handbook (1992) Aspen Global Change Institute, 100 East Francis Street, Aspen, Co. 81611

INTERNET

http://www.nasm.edu/ceps/reflect/
Reflections on Earth: Exploring Planet Earth from Space, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution

http://www.si.edu/crc/
National Zoological Park's Conservation and Research Center, Smithsonian Institution

http://www.si.edu/simab/
Monitoring and Assessment of Biodiversity Program, National Museum of Natural History, Smithsonian Institution

http://see.gsfc.nasa.gov/edu/SEES/globa/class/G_class.htm
NASA's Studying Earth's Environment from Space: Global Land Vegetation Module

http://www.gap.uidaho.edu/
The U.S. Geological Survey's Gap Analysis Project (A Geographical Approach to Planning for Biodiversity)

http://www.conservation.org/science/nasa/overview.htm
Global Land Cover for Biodiversity Analysis, Conservation International

http://globe.fsl.noaa.gov/fsl/welcome.html
The Globe Program, NOAA/Forecast Systems Laboratory, Boulder, Colorado

http://terraserver.microsoft.com
Microsoft TerraServer is a database on the Web comprising a repository of aerial photographs and satellite images that can be viewed and purchased online.

http://rst.gsfc.nasa.gov/TofC/Coverpage.html
The Remote Sensing Tutorial is sponsored by the Applied Information Sciences Branch at NASA's Goddard Space Flight Center.

http://www.usgs.gov/Earthshots
The U.S. Geological Survey's Earthshots is a collection of Landsat images and text, designed to show environmental changes and to introduce remote sensing.

http://earthexplorer.usgs.gov
USGS EarthExplorer is an interactive computer system developed by the U.S. Geological Survey for sources of satellite imagery, aerial photographs, and cartographic products.

http://www.wri.org/biodiv/biodiv.html
World Resources Institute

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