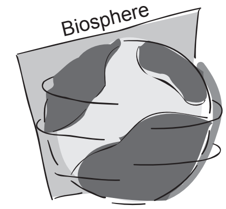


Introduction

The Big Picture

Earth's surface is two-thirds water. The continents on which we live make up the remainder. Until the launch of the first humans into space, we did not fully appreciate the beauty and diversity of our planet. We rely on Earth's surface (and a little bit above and below) to supply most of what we need to live. Therefore, mapping and monitoring this surface is critical to our wise use and protection of it. The Biosphere Investigation deals with the mapping and monitoring of both the surface and phenological indicators.

Remote sensing simply means learning something about an object without making direct contact with it. We use remote sensing every day by hearing, smelling, and seeing. Historically we have used aerial photographs taken from balloons, airplanes, and more recently, digital images acquired by orbiting satellites, to map and monitor Earth's biosphere.

Remote sensing from space has the great advantages of being able to cover very large areas quickly and to revisit the same area frequently. However, some of the detail that can be seen at ground level may not be detected by a remote sensing system. Therefore, it is beneficial to collect data at sample sites on the ground to accompany remotely sensed data about an area. It is not possible to effectively visit every place on Earth to map the land cover. Instead, we rely on samples – actual ground visits – and relate these samples to what we can see using various remote sensing systems.

Remote sensing observations of the land surface are usually presented as digital images. Each element of such an image is a *pixel* or picture element. The size of the pixels depends on the spatial resolution of the remote sensing instrument. Spatial resolution refers to the size of the smallest object or area that can be distinguished from its surroundings. The Landsat Thematic Mapper (TM), utilized on earlier Landsat satellites, and the Operational Land Imager (OLI), utilized on Landsat 8, has provided remotely sensed imagery useful in land cover and phenology monitoring since 1972. Landsat images have a spatial resolution, or pixel size, of 30 m x 30 m. See Figure BIO-I-1. For more information on remote sensing, refer to the *Remote Sensing* section of the *Implementation Guide*.

Phenology, the study of living organisms' response to seasonal changes in their environment, includes both plant and animal responses. Broad-area estimates of the lengths of growing seasons are primarily based on remotely sensed satellite data. However, remote sensing estimates from satellites are not exact because the actual behavior of the plants must be inferred from the collective appearance of their foliage. GLOBE student observations, the first global network of ground-based plant phenology observations, will help scientists validate their estimates of global greenness values that they derive using satellite data. Monitoring the length of the growing season is important for society so that it can better adapt to variations in the length of the growing season and to other impacts of climate change, which may affect food production, economic growth, and human health.

Spectral resolution refers to the wavelengths of light, commonly called bands, the satellite image sensors are capable of measuring. Our eyes also sense different wavelengths of light (colors), but we only see in a range of wavelengths known as the visible portion of the electromagnetic spectrum. Landsat 8 satellite carries two instruments: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Landsat 8 images consist of 11 spectral bands. Bands 1 through 4 are visible, band 5 is near-infrared (NIR), bands 6 and 7 are shortwave infrared (SWIR), band 8 is panchromatic, band 9 is useful for detecting cirrus clouds (as well as other cloud types), and bands 10 and 11 are thermal infrared (TIR). Resolution for all these bands is 30 meters except for band 8, panchromatic, which is 15 meters, and bands 10 and 11 which are 100 meters. More information on Landsat 8 bands, as well as images of the same location using different bands, can be found at: http://landsat.gsfc.nasa.gov/?page_id=5377.

Scientists use satellite images of remotely sensed data as tools to help make maps of land cover types as well as to monitor vegetative health and the length of the growing season. An important issue that arises regarding land cover maps is, “How good are land cover maps made from remotely sensed data?” The way to answer this question is to conduct an accuracy assessment of the remotely sensed map. If appropriate sample land cover sites are visited on the ground, then these samples can be compared to the same areas on the map and a measure of map accuracy determined. In this way, we can evaluate how good our land cover maps are. This assessment is very useful when it comes to making important decisions about Earth’s land cover from these maps. Satellite imagery can be used to determine growing season as well; however for the most accurate data, satellite images are often combined with ground validation data.

Finally, it is important that the ground samples and the remote sensing maps use the same classification system. A classification system consists of a list of labels or land cover types and the corresponding definitions for each label. Since The GLOBE Program is a world-wide effort, it is important that the classification system chosen be appropriate for any place on Earth. In The GLOBE Program, we have modified a widely accepted system developed by UNESCO (United Nations Educational, Scientific and Cultural Organization) to include both natural and developed land cover. This system is called the Modified UNESCO Classification (MUC) System. Everyone in The GLOBE Program uses MUC to label land cover sample sites visited on the ground as well as the maps made from the remotely sensed data. Therefore, a consistent and uniform land cover map can be created for the entire world and validated.

Why Collect Carbon Data?

The global carbon cycle is a key regulator of the Earth’s climate and is central to the normal function of ecological systems. By participating in GLOBE Carbon Cycle, students learn to use a systems thinking approach, while at the same time gaining a foundation in the carbon cycle and its relation to climate and energy. Measuring plant growth (biomass) and carbon storage of vegetation at a sample site or school yard allows us to look at the bigger picture of carbon storage and provides a reference point to consider when making management decisions in the light of climate change. Should these trees be logged? Should more trees be planted? If the biomass of the same trees is then monitored over several years you can begin to look at growth, carbon uptake over time, another important component in the global carbon cycle equation. Carbon uptake from the atmosphere is particularly interesting because it is the opposite of carbon emissions to the atmosphere, typically calculated through a carbon footprint assessment.

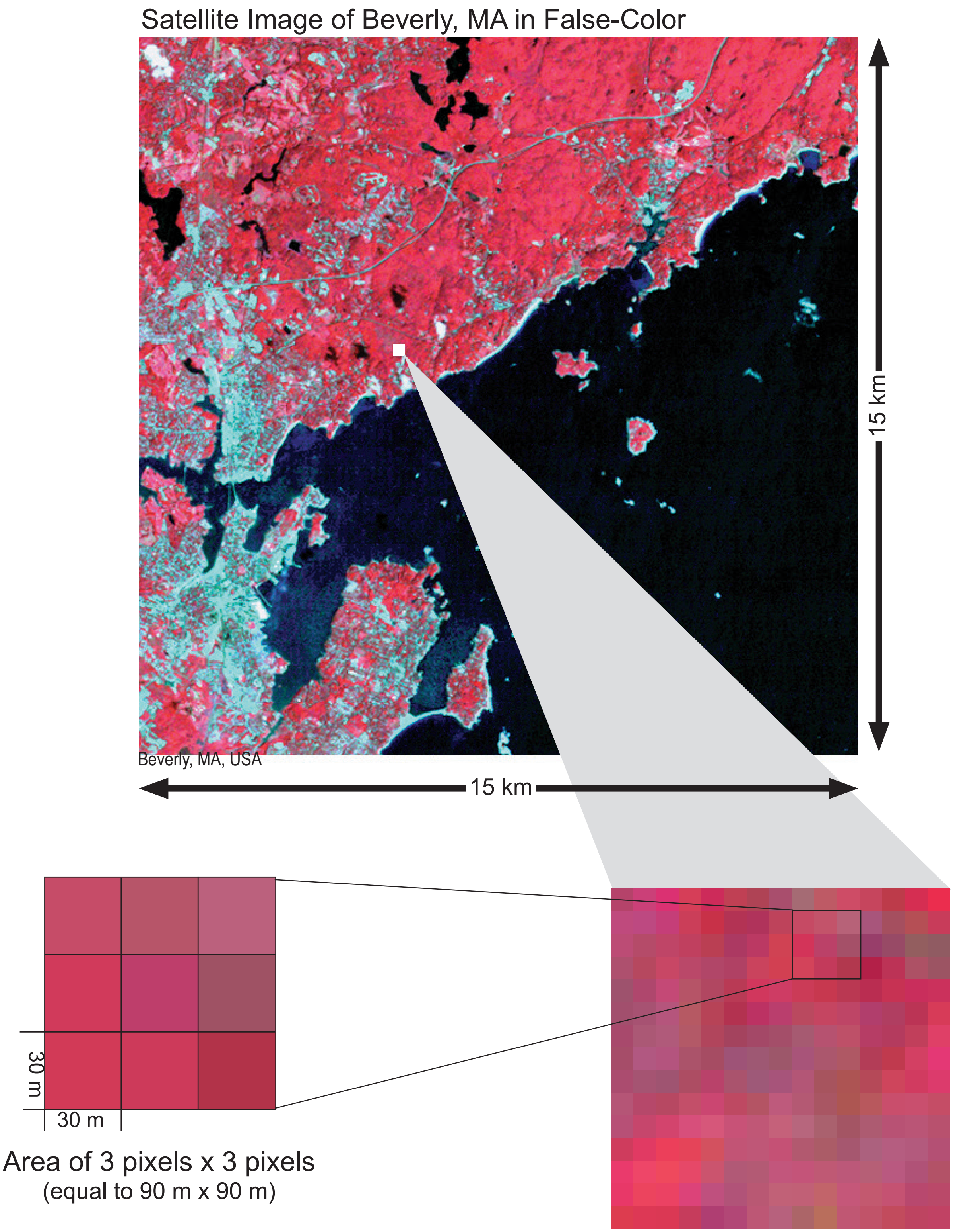
Why Study Phenology?

Each year, as conditions for plant growth improve, a wave of green spreads over the land surface (green-up) and then retreats as conditions for plant growth decline (green-down). These waves are important because they are directly related to global carbon fixation and the amount of carbon dioxide (CO_2) in the atmosphere. The period between green-up and green-down or *senescence* is known as the *growing season*, and changes in the length of the growing season may be an indication of global climate change. For example, some scientists recently found that the growing season has increased in northern latitudes by eight days since the early 1980s. However, their conclusion is controversial because it was based only on satellite data. On-the-ground observations of plant green-up and green-down are needed to validate these types of satellite estimates.

Why Take Phenology Measurements

Estimates based on remote sensing data from satellites vary because of problems such as interference from small and large clouds, atmospheric haze, and other atmospheric properties that affect the greenness values that satellites detect. Other problems such as low sun angles at high latitudes, change of sun angle with seasons, poor viewing geometry, and aging of satellite detectors can affect scientist’s estimates of greenness as well. GLOBE student observations will help scientists validate their estimates of global growing season changes that they derive

Figure BIO-I-1: Example Satellite Image



As you zoom in on a 15 km x 15 km satellite image, the pixels (which are 30 m x 30 m in size) become visible. In the *Land Cover/Biology Investigation*, students take field measurements at sites that are 90 m x 90 m (equal to 3 pixels x 3 pixels).

using satellite data.

Why Investigate Land Cover?

Land cover is a general term used to describe what is on the ground or covering the land. Different land cover terms are used to describe the differences we see when we look at the land. Land cover can include where we live (in houses or apartments), where we do business and produce goods and services (commercial and agriculture areas) and how we travel (on roads, trains, and from airports). It is also a term that is used to describe different natural habitats; desert, forest, woodland, wetland, glaciers and water bodies, among others. All living things depend on their habitat, their land cover, for survival. They find shelter there, they find food there, and they find protection there. Land cover has a direct effect on the kinds of animals that will likely inhabit an area. Therefore, land cover is of great interest to ecologists, who study how plants and animals relate to their environment.

Land cover can influence weather, soil properties, and water chemistry. Different land cover types are all distinct in their effects on the flow of energy, water and various chemicals between the air and surface soil. Natural land cover, meaning land cover that is not the result of human activity, is often an indication of the climate of an area. For instance, forests may be found on the wet side of a mountain while in the rain shadow on the other side there may be shrubland. In a coastal region with frequent fog, the plants that grow there modify the soil over time. The land cover in such an area is a community of trees, shrubs, and other plants indicative of a foggy coast. Large rainforests actually create their own weather with daily rain showers. In deserts, plants adapted to dry conditions dominate the land cover.

Knowing the type of land cover in a region helps us understand the local climate. For scientists studying atmosphere, soil and hydrology, the type of land cover surrounding measurement sites is an important piece of information. This type of information is often referred to as *metadata* and helps provide a context for evaluating data collected by the scientists or students on that site. However, for land cover scientists, land cover data provide much more than that.

Mapping

Data collected at land cover sample sites visited on the ground help land cover scientists create and label land cover maps produced from satellite images and aerial photographs. Additional independent ground sample sites help verify how accurate these maps are. Data from ground sample sites such as detailed biometric observations (measurements of living things) help Earth systems scientists improve their ability to interpret satellite imagery.

Monitoring

Land cover maps are used to monitor endangered plants, animals and habitats, economic development, land use, fire fuel management, cropland management, wetland loss, effects of environmental change in ecosystems and other changes in land cover over time. The list of uses is long once scientists have access to accurate and precise land cover data.

Biometry data collected in the field assist scientists in monitoring the amount of nutrients, water and gases in vegetation. This is helpful in understanding Earth systems, including: nutrient cycles, the energy cycle and the hydrological cycle. Land cover influences these cycles in a variety of ways. One example is how solar radiation, reflected by land and vegetation, affects regional and global climate patterns. Since land cover is a component of numerous systems, monitoring its characteristics will provide more information for understanding global ecological systems. Plants are part of nutrient cycles and hydrological cycles and they can be used as indicators to monitor changes in these systems. Remotely sensed data that discriminate between various kinds of vegetation may be used to determine health and density of plants, but require ground observations to quantify and calibrate these relationships.

Scientists Need GLOBE Data

Scientists collect ground data to learn as much about Earth as they can. Ideally, Earth systems scientists would like to have information about every place on our planet. The more ground data the better. Practically, it is only possible to collect this information for a small sample of areas. Remote sensing provides a means of relating observations and measurements on the ground to the larger regional and global views. Ground data are needed to learn about sample areas and to validate (i.e., compare with) the maps generated from remotely sensed data. At a GLOBE school, students can significantly add to the limited supply of ground information. No other group in the world is collecting a uniform dataset such as this. Therefore, GLOBE schools are providing unique, valuable information that will help scientists better understand Earth. Through participation in the *Biosphere Investigation Land Cover data collection protocols and the Mapping* learning activities, GLOBE students will significantly help Earth systems science while increasing their own knowledge and understanding of the scientific process, ecological systems and their surrounding landscape.

Educational Objectives

Students participating in the activities presented in this chapter should gain scientific inquiry abilities and understanding of a number of scientific concepts. These abilities include the use of a variety of specific instruments and techniques to take measurements and analyze the resulting data along with general approaches to inquiry. The Scientific Inquiry Abilities listed in the grey box are based on the assumption that the teacher has completed the protocol including the Looking at the Data section. If this section is not used, not all of the Inquiry Abilities will be covered. The Science Concepts included are outlined in the United States National Science Education Standards as recommended by the US National Research Council and include those for Earth and Space Science, Physical Science, and Life Science. The Geography Concepts are taken from the National Geography Standards prepared by the National Education Standards Project. Additional Enrichment Concepts specific to the land cover measurements and mapping have been included as well. The gray box at the beginning of each protocol or learning activity gives the key scientific concepts and scientific inquiry abilities covered. The following tables provide a summary indicating which concepts and abilities are covered in which protocols or learning activities.

Standards for Carbon Cycle

https://www.globe.gov/documents/355050/14396119/NGSS_Correlation_Matrix.pdf

National Science Education Standards	Land Cover Protocols		Phenology Protocols					
	Sample Site	Biometry	Green-Up & Green-Down	Ruby-throated Hummingbird	Phenological Gardens	Cloned & Common Lilacs	Arctic Bird Migration	Seaweed Reproductive Phenology
Earth And Space Sciences								
Changes in the Earth and Sky (K-4)								
Weather changes from day to day over the seasons			■	■	■	■		
Weather can be described by measurable quantities								
Properties of Earth Materials (K-4)								
Soils have properties of color, texture and composition; they support the growth of many kinds of plants								
Structure of the Earth System (5-8)								
Soil consists of weathered rocks and decomposed organic matter								
Water circulates through the biosphere, lithosphere, atmoshpere and hydrosphere (water cycle)								
Energy in the Earth System (9-12)								
The sun is the major source of energy at Earth's surface			■	■	■	■		
Physical Science Concepts								
Properties of Objects and Material (K-4)								
Objects have observable properties	■	■						
Position and Motion of Objects (K-4)								
Position of objects can be described by locating it relative to another object	■							
Life Science Concepts								
The Characterization of Organisms (K-4)								
Organisms have basic needs			■	■	■	■	■	■
Organisms can only survive in environments where their needs are met			■	■	■	■	■	■

National Science Education Standards	Land Cover Protocols		Phenology Protocols					
	Sample Site	Biometry	Green-Up & Green-Down	Ruby-throated Hummingbird	Phenological Gardens	Cloned & Common Lilacs	Arctic Bird Migration	Seaweed Reproductive Phenology
Earth has many different environments that support different combinations of organisms	■	■	■	■	■	■	■	■
Organisms and their Environments (K-4)								
Organisms' functions relate to their environment			■	■	■	■	■	■
Organisms change the environment in which they live		■	■		■	■		■
Humans can change natural environments								
Life Cycles of Organisms (K-4)								
Plants and animals have life cycles			■	■	■	■	■	■
Plants closely resemble their parents			■		■	■		■
Structure and Function of Living Systems (5-8)								
Ecosystems demonstrate the complementary nature of structure and function								
Regulation and Behavior (5-8)								
All organisms must be able to obtain and use resources while living in a constantly changing environment				■	■	■	■	
Populations and Ecosystems (5-8)								
All populations living together and the physical factors with which they interact constitute an ecosystem	■	■						
The Interdependence of Organisms (9-12)								
Humans can change ecosystem balance								
Organisms both cooperate and compete in ecosystems				■			■	
The population of an ecosystem is limited by its resources				■			■	
Matter, Energy, and Organization in Living Systems (9-12)								
Energy for life derives mainly from the sun			■		■	■		■

National Science Education Standards	Land Cover Protocols		Phenology Protocols					
	Sample Site	Biometry	Green-Up & Green-Down	Ruby-throated Hummingbird	Phenological Gardens	Cloned & Common Lilacs	Arctic Bird Migration	Seaweed Reproductive Phenology
Living systems require a continuous input of energy to maintain their chemical and physical organizations			■		■	■		■
The Behavior of Organisms (9-12)								
The interaction of organisms in an ecosystem have evolved together over time				■			■	
Geography Concepts								
How to Use Maps (real and imaginary (K-4))	■							
The Physical Characteristics of Place (K-4)	■	■						
The Characteristics and Spacial Distribution of Ecosystems (K-12)	■	■						
How humans modify the environment								
The World in Spatial Terms (K-12)								
Plants help to define the character and spatial distribution of ecosystems on the Earth's surface					■			
General Scientific Inquiry Abilities								
Use appropriate tools and techniques								
Construct a scientific instrument or model								
Identify answerable questions	■	■						
Design appropriate mathematics to analyze data	■	■						
Develop descriptions and explanations using evidence	■	■						
Recognize and analyze alternate explanations	■	■						
Communicate procedures and explanations	■	■						

National Science Inquiry Standards	Land Cover Protocols		Phenology Protocols					
	Sample Site	Biometry	Green-Up & Green-Down	Ruby-throated Hummingbird	Phenological Gardens	Cloned & Common Lilacs	Arctic Bird Migration	Seaweed Reproductive Phenology
General Scientific Inquiry Abilities								
Use appropriate tools and techniques								
Construct a scientific instrument or model								
Identify answerable questions	■	■						
Design appropriate mathematics to analyze data	■	■						
Develop descriptions and explanations using evidence	■	■						
Recognize and analyze alternate explanations	■	■						
Communicate procedures and explanations	■	■						
Specific Scientific Inquiry Abilities								
Use appropriate field instruments and techniques to gwther Land Cover sample	■							
Make observations in order to determine the appropriate land cover type	■							
Communicate the results of land cover classification to reach consensus	■							
Identify biometry measurements needed for MUC		■						
Use vegetation field guides to identify vegetation and species		■						
Interpret data to propose MUC classification		■						
Classify land cover and create a land cover type map								
Evaluate how accurate the land cover type map is using accuracy assessment								
Use land cover data and appropriate tools and technology to interpret change								
Gathering spatial data and historical data to determine validity of change hypothesis								

National Science Inquiry Standards	Land Cover Protocols		Phenology Protocols					
	Sample Site	Biometry	Green-Up & Green-Down	Ruby-throated Hummingbird	Phenological Gardens	Cloned & Common Lilacs	Arctic Bird Migration	Seaweed Reproductive Phenology
Use maps, aerial photographs and other tools and techniques in order to create a land cover map								
Recognize and analyze differing viewpoints on land cover classification and reach consensus								
Integrate data from a variety of different data sets to gain dynamic understanding of how earth system works								
Classification helps organize and understand the natural world								
A classification system is a system of labels and rules used to sort objects								
A hierarchical system has multiple levels of increasing detail								
Observe a landscape and design a model of it								
Draw a landscape from various perspectives								
Use different scales to view a group of objects								
Identify decision criteria for a classification system, and use it to classify birds								
Collect and interpret validations data								
Use numerical data in describing and comparing the accuracy of the classification								
Use the land cover type map to discuss how a structure will affect organisms using a particular land cover type								
Analyze different scenarios that change the land cover types of an area								
Evaluate different solutions to various scenarios								
Use the GLOBE website to gather, interpret and Interpret data								

National Science Education Standards	Land Cover Learning Activities									
	Manual Mapping	Computer-Aided Mapping	Land Cover Change	Getting to Know Your Satellite Imagery	Site Seeing	Leaf Classification	Odyssey of the Eyes	Bird Beak Accuracy	Discovery Area	Using GLOBE Data
Physical Science Concepts										
Properties of Objects and Material (K-4)										
Objects have observable properties						■		■		
Position and Motion of Objects (K-4)										
Position of objects can be described by locating it relative to another object										
Life Science Concepts										
The Characterization of Organisms (K-4)										
Earth has many different environments that support different combinations of organisms			■		■				■	
Organisms and their Environments (K-4)										
Organisms' functions relate to their environment										
Organisms change the environment in which they live			■					■		
Humans can change natural environments			■	■						
Structure and Function of Living Systems (5-8)										
Ecosystems demonstrate the complementary nature of structure and function									■	
Regulation and Behavior (5-8)										
All organisms must be able to obtain and use resources while living in a constantly changing environment			■							
Populations and Ecosystems (5-8)										
All populations living together and the physical factors with which they interact constitute an ecosystem		■	■		■		■			■

National Science Education Standards	Land Cover Learning Activities									
	Manual Mapping	Computer-Aided Mapping	Land Cover Change	Getting to Know Your Satellite Imagery	Site Seeing	Leaf Classification	Odyssey of the Eyes	Bird Beak Accuracy	Discovery Area	Using GLOBE Data
The Interdependence of Organisms (9-12)										
Humans can change ecosystem balance			■						■	
Geography Concepts										
How to Use Maps (real and imaginary (K-4))			■	■	■		■			■
The Physical Characteristics of Place (K-4)			■	■	■		■			■
The Characteristics and Spacial Distribution of Ecosystems (K-12)	■	■	■	■	■		■			■
How humans modify the environment	■	■	■		■		■		■	■

National Science Inquiry Standards	Land Cover Learning Activities									
	Manual Mapping	Computer-Aided Mapping	Land Cover Change	Getting to Know Your Satellite Imagery	Site Seeing	Leaf Classification	Odyssey of the Eyes	Bird Beak Accuracy	Discovery Area	Using GLOBE Data
General Scientific Inquiry Abilities										
Use appropriate tools and techniques										
Construct a scientific instrument or model										
Identify answerable questions	■	■	■	■	■	■	■	■	■	■
Design appropriate mathematics to analyze data	■	■	■	■	■	■	■	■	■	■
Develop descriptions and explanations using evidence	■	■	■	■	■	■	■	■	■	■
Recognize and analyze alternate explanations	■	■	■	■	■	■	■	■	■	■
Communicate procedures and explanations	■	■	■	■	■	■	■	■	■	■
Specific Scientific Inquiry Abilities										
Use appropriate field instruments and techniques to gwther Land Cover sample										
Make observations in order to determine the appropriate land cover type										
Communicate the results of land cover classification to reach consensus										
Identify biometry measurements needed for MUC										
Use vegetation field guides to identify vegetation and species										
Interpret data to propose MUC classification										
Classify land cover and create a land cover type map	■	■								
Evaluate the accuracy of a land cover type map using accuracy assessment	■	■								
Use land cover data and appropriate tools and technology to interpret change			■							
Gathering spatial data and historical data to determine validity of change hypothesis			■							

National Science Inquiry Standards	Land Cover Learning Activities									
	Manual Mapping	Computer-Aided Mapping	Land Cover Change	Getting to Know Your Satellite Imagery	Site Seeing	Leaf Classification	Odyssey of the Eyes	Bird Beak Accuracy	Discovery Area	Using GLOBE Data
Use maps, aerial photographs and other tools and techniques in order to create a land cover map				■						
Recognize and analyze differing viewpoints on land cover classification and reach consensus				■						
Integrate data from a variety of different data sets to gain dynamic understanding of how earth system works					■					
Classification helps organize and understand the natural world						■				
A classification system is a system of labels and rules used to sort objects						■				
A hierarchical system has multiple levels of increasing detail						■				
Observe a landscape and design a model of it							■			
Draw a landscape from various perspectives							■			
Use different scales to view a group of objects							■			
Identify decision criteria for a classification system, and use it to classify birds								■		
Collect and interpret validation data								■		
Use numerical data for describing and comparing the accuracy of the classification								■		
Use the land cover type map to discuss how a structure will affect organisms using a particular land cover type									■	
Analyze different scenarios that change the land cover types of an area									■	
Evaluate different solutions to various scenarios									■	
Use GLOBE website to gather, analyze and interpret data										■

National Science Education Standards	Phenology Learning Activities				
	Green-up Cards	A Sneak Preview of Budburst	A First Look at Phenology	A Beginning Look at Photosynthesis	Investigating Leaf Pigments
Earth and Space Sciences					
Changes in Earth and Sky (K-4)					
Weather changes from day to day and over the seasons					
Seasons result from variations in solar insolation resulting from the tilt of the Earth's rotation axis	■				
Energy in the Earth System (9-12)					
The sun is the major source of energy at Earth's surface		■			
Solar insolation drives atmospheric and ocean circulation		■			
Earth in the Solar System (5-8)					
The sun is a major source of energy for phenomena on Earth's surface					
Geochemical Cycles (9-12)					
Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere)		■			
Physical Sciences					
Energy: Transfer and Conservation (5-8)					
Heat energy is transfered by conduction, convection and radiation					
Heat moves from warmer to colder objects					
The sun is a major source of energy for changes on the Earth's surface	■	■			
Energy is conserved					
Chemical Reactions (9-12)					
Chemical reactions take place in every part of the environment		■			■
Life Sciences					
The Characteristics of Organisms (K-4)					
Organisms can only survive in environments where their needs are met		■			
Earth has many different environments that support different combinations of organisms	■		■		
Organisms and their Environments (K-4)					
Organisms' functions relate to their environment	■	■	■	■	
Organisms change the environment in which they live	■	■			
Humans can change natural environments					

National Science Education Standards	Phenology Learning Activities				
	Green-up Cards	A Sneak Preview of Budburst	A First Look at Phenology	A Beginning Look at Photosynthesis	Investigating Leaf Pigments
Life Cycles of Organisms (K-4)					
Plants and animals have life cycles	■		■	■	
Structure and Function of Living Systems (5-8)					
Ecosystems demonstrate the complementary nature of structure and function					
Regulation and Behavior (5-9 & 9-12)					
All organisms must be able to obtain and use resources while living in a constantly changing environment	■	■		■	
Populations and Ecosystems (5-8)					
All populations living together and the physical factors with which they interact constitute an ecosystem					
Populations of organisms can be categorized by the function they serve in the ecosystem	■				
Sunlight is the major source of energy for ecosystems	■	■			
The number of animals, plants and microorganisms an ecosystem can support depends on the available resources	■				■
The Interdependence of Organisms (9-12)					
Atoms and molecules cycle among the living and non-living componenets of the ecosystem		■			
Energy flows through ecosystems in one direction (photosynthesis-herbivores-carnivores-decomposers)	■			■	
The population of an ecosystem is limited by its resources	■				
Humans can change ecosystem balance					
Matter, Energy, and Organization in Living Systems (9-12)					
Energy for life derives mainly from the sun	■	■			
Living systems require a continuous input of energy to maintain their chemical and physical organizations	■	■			■
The Behavior of Organisms (9-12)					
The interaction of organisms in an ecosystem have evolved together over time	■				

Measurement Logistics

Overview

The Biosphere Investigation involves studying both the phenological observations near your school as well as the land cover in a much larger area. Land cover sample sites are within a much wider geographic area, since in most cases you will visit them only once.

Carbon Cycle

Carbon data can be collected at "Standard" or "Non-Standard" sites. Standard sites are areas of at least 225 m^2 that have contiguous vegetation (e.g. a forest, grassland). Non-Standard sites are areas with some vegetation and some human interference (e.g. a school yard or city park). See the Site Selection Protocol for more detail. Depending on the type of site, students will follow slightly different protocols for determining biomass and carbon storage of the vegetation present (look for "Standard" and "Non-Standard" in the protocol titles). Similar to Land Cover, starting with local maps and/or satellite images (i.e. using Google Maps and Google Earth) to get a basic idea of the vegetation in your schoolyard area and surrounding region can be helpful in choosing a site.

Phenology

GLOBE offers five plant and two animal phenology protocols: the plant phenology protocols consist of Green-up and Green-down (these can be implemented individually, however these data are most useful when collected at the beginning and end of the growing season, respectively), Phenological Gardens, Cloned Lilacs, and Seaweed Reproductive Phenology. The animal phenology protocols consist of Ruby-throated Hummingbird observations and Arctic Bird Migration monitoring. Phenology observations, depending on which protocol(s) you and your students select (or which are applicable to your geographic location) should be conducted near your school as they should be done daily to every two to three days. The exception to this is the Seaweed Reproductive Phenology Protocol, which is done once a month for four months in a row.

Land Cover

Land cover sample sites must be 90 m X 90 m in size and homogeneous (contain the same land cover type throughout). Students will be collecting data about the type of land cover present. A good place to begin is by having students observe their school and surrounding area in an aerial photograph. After students have identified their school and other easily identifiable locations in an aerial photograph, have them view the same location in a satellite image. Can they recognize some of the same locations as they did in the aerial photograph? What types of land cover are recognizable (airports, large bodies of water, major roads, etc.).

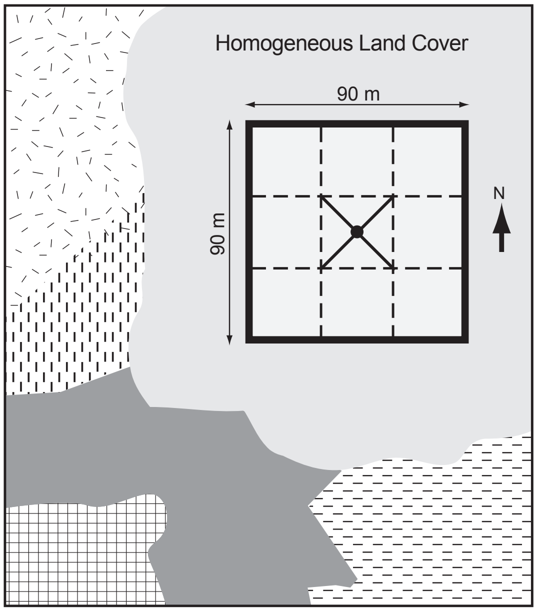
For information on obtaining satellite imagery of your location see http://www.globe.gov/about-globe/faq/overview/remote-sensing/no-landsat. As you build an understanding of the land cover in your area, you will create a land cover type map from the satellite image. Ultimately, changes over time in land cover are studied through a comparison of two co-registered satellite images of the same area and the accompanying ground measurement data that you have collected. The images are acquired a few years apart and you can compare the changes that occur between the two dates.

Where are measurements taken?

Land Cover measurements can be taken anywhere that consists of a large homogeneous land cover type. It is not expected that you and your students will return to these sites as with other GLOBE protocols. The exception is when the cover has changed due to fire, flood or man-made modification. By performing the protocols and learning activities associated with this part of the investigation, you and your students will become intimately familiar with this part of our global environment. Together, you can create and validate a land cover type map of your area.

It is important that you select appropriate ground validation sites for observation and detailed measurements. Once completed, perhaps over several years, you and your students will have visited at least one land cover sample site for every type of land cover that exists in your area. For areas

Figure BIO-I-2: Homogeneous Land Cover



of homogeneous land cover larger than 90 m x 90 m, locate your land cover sample site near the center of the area (see Figure BIO-I-2). A sample site area of 90 m x 90 m is necessary in order to accurately locate the site on the ground and on the satellite image. This area is equivalent to nine Landsat pixels (a square of 3 pixels by 3 pixels). See the *Remote Sensing* section of the *Implementation Guide*.

You may collect data from areas outside the area displayed on a satellite image as well. For instance, some schools make periodic visits to remote natural sites such as national parks. They collect data while on these field trips and report their measurements to GLOBE. If your school will make repeated visits to such a remote location, you should aquire a Landsat image for this site so that you can do all aspects of the *Land Cover* portion of the *Biosphere Investigation* for this additional area.

What measurements are taken?

Essential for all GLOBE data collection protocols is a precise location which includes the latitude, longitude and elevation using a GPS (Global Positioning System) receiver or other reliable source.

GLOBE's phenology measurements consist of the following:

Green-up: report the date of budburst and leaf growth

Green-down: report the dates of color changes in leaves

Ruby-throated Hummingbird: observe seasonal migration patterns, feeding habits, and nesting behavior of Ruby-throated Hummingbirds (applicable for students in North and Central America)

Phenological Gardens: report the flowering and leaf stages of select garden plants

Lilac Phenology: record the five phenophases of either common or cloned lilac plants

Arctic Bird Migration Monitoring: record first arrival date and numbers of select migratory bird species at your site until few or none are seen

Seaweed Reproductive Phenology: classify and count reproductive phenological phases of receptacles on select seaweed species

GLOBE's land cover measurements consist of the following:

Land Cover Sample Site: classify land cover types according to the MUC system and take photographs in the cardinal directions

Biometry measurements: In some instances additional measurements are required to determine the classification of natural land cover types

Fire Fuel: measure the different types of fuels (i.e., dead branches, logs, live shrubs and trees) for fire in land cover sample sites

The Land Cover protocols are intended to lead into a land cover mapping activity. These maps can either be created by hand following the *Manual Land Cover Mapping Learning Activity* or through the use of MultiSpec software following the *Computer-aided Land Cover Mapping Learning Activity*. The culmination of the lanc cover portion of the Biosphere Investigation involves comparing satellite images of the your location acquired a few years (approximately 10 years) apart to study land cover change over time by following the *Land Cover Change Detection Learning Activity*. The final map products can be included in student research reports, shared on the GLOBE website and shared with your community as a valuable natural resources and urban planning tool. These maps are created to learn more about your surroundings by taking observations and measurements at selected sample locations.

GLOBE's Carbon measurements consist of the following:

All Carbon Cycle sampling begins with the Site Set-up Protocol which only needs to be completed once. Once the site is set up, the measurements taken depend upon the vegetation present. Students can use the Protocol Decision Tree to help make this determination. All sites containing trees will complete Tree Mapping and Tree Circumference Protocols. At some sites students will also complete the Shrub/Sapling Protocol and/or the Herbaceous Protocol. These protocols can all be done in conjunction with each other. [Note: All links are for Standard Sites, Non-Standard Protocols can be seen from the GLOBE Carbon Cycle page.]

Upon completing the Biosphere Investigation, you and your students will know a great deal about the environment surrounding your school and you will be able to monitor change as it happens. For your school, these protocols can last anywhere from 15 minutes every other day to days, weeks, months, or even years. Please refer to the specific section on the *Mapping and Accuracy Assessment Process* for more details.

When are measurements taken?

Timing is everything, and the timing of when measurements within the Biosphere Investigation is key to collecting valuable data. Phenological data tell a specific story of what is occuring in the environment. Therefore timing when to begin to collect phenology data is vital. In order to observe budburt or the first color change on a leaf it's important to begin observing perhaps two weeks prior to the anticipated occurance. In order to see the first arctic tern arrive at your site you need to begin observing perhaps two weeks prior to the anticipated arrival. In order to discover these dates and know when you should begin making observations, you may need to seek out the advice and knowlege of farmers, ecologists, and other individuals within your community.

The best time to take the measurements for the Land Cover Sample Site and Biometry protocols is during the peak of the growing season. This is when it is best to assess the land cover class of the site and the full canopy and ground cover. If you are going to visit a site repeatedly and take biometry or carbon measurements to monitor changes in biomass over time for a period of years, you can visit the site once every year at the same time of year. Or, if you would like to track changes in biomass throughout the year, you many choose to visit a site twice a year or more, once during the peak of the growing season and once during minimum growth (ex. dry season or winter). The mapping learning activities can be performed at any time of year.

Special Considerations

A number of time management, educational, and logistical issues should be considered in deciding how to present and undertake the various Bio*sphere Protocols*.

- Plant phenology protocols (*Green-up*, *Green-down*, *Phenological Gardens*, *and Cloned Lilacs*) should be conducted on plants that are not artificially watered (through either irrigation or sprinkling).
- Plants (e.g., trees) observed as a part of *Green-up* or *Green-down* protocols should be easily accessible.
- Select native species of trees for *Green-up* and *Green-down* protocols if possible.
- Land cover data can be collected from all land cover classes as long as the sites are homogeneous and at least 90 m x 90 m in size.
- Biometry measurements in Land Cover Sample Sites are very useful and offer students a more complete view of the land cover assessment process. They are used to decide the correct land cover class for a Land Cover Sample Site.
- Land Cover Sample Site observations are useful and can be quickly and efficiently collected in sufficient number to validate (or assess the accuracy of) your land cover type map generated from a Landsat image.

- Students benefit from practicing biometry or carbon measurements before going to their Land Cover or Carbon Sample Sites. Practicing before going into the field can lessen the amount of time it takes to collect the observations at the site.
- If a GPS receiver and a camera are available, observation of a Land Cover Sample Site can be accomplished quickly. If they are not, you will have to return to the site to complete the observations. It would be to your benefit to have these with you in the field.
- Schools should collect as many Land Cover Sample Sites as possible for each land cover type present on their land cover type map because many samples are needed to assess the accuracy of the map. Sites collected in different years, by different classes, or even neighboring schools can all be used in the accuracy assessment process.
- Be sure to note the difference between naturally vegetated sites and cultivated sites.
- Review the *Glossary of Terms* to make sure that you understand the terms used throughout the *Biosphere Investigation*.

Getting Started

Using the *Land Cover/Biology Protocols*, you and your students can explore the land cover in your GLOBE Study Site and answer questions that are relevant to your particular area, region and/or students. Land cover map creation is just one step for scientists. Once they have created this map, they can use and modify it in order to study a specific question they are researching. For instance, scientists may be studying the habitat of a certain animal or plant, the succession of fields to forests or the rate of growth of a particular village, town or city. They may also be looking at the amount of undeveloped land, how to protect water resources, or where to plant certain crops during the next growing season. Town planners may be interested in creating a map in order to decide new school boundaries, where to connect recreational trails to create one continuous system or how to efficiently run public transportation. These are just some possible uses of your maps. By creating a base map, you and your students have a powerful tool to begin to look at what your students feel is important in their particular area.

There are many ways to begin your investigation of the biosphere. One of the simplest and quickest is to use the learning activity, *Getting to Know Your Satellite Imagery*. It is an exploration of the imagery. From there, you and your students can begin to notice the "pattern" of land cover in your area. This may bring up community issues that interest your students – water bodies that need protection, land that is being eroded, a trail system that can be connected to other systems, etc. Alternatively, a discussion about growing season and whether it might be getting longer could lead your students becoming interested in monitoring local phenoloical markers. Beginning with these ideas, introduce the protocols as a way to explore these issues further. The student introduction page for each of the protocols offers some questions that your students should be thinking about to be in the correct "mindset" for that protocol. It introduces the kind of data they will be collecting, asks students to think about why they are collecting that particular data, and then asks them how they can apply it to their own questions. By beginning with the learning activity or the protocols themselves, the *Biosphere Investigation* leaves it to your students to choose what particular part of their environment they want to explore. If your students are hesitant about generating their own questions or do not have an idea where to begin, just collecting the Green-up or Green-down measurements (depending on the season) or Land Cover Sample Site data and working on the land cover map is a great start, and may help them to come up with their own questions. The *Land Cover Change Detection Learning Activity* also can serve as a basis for the question: What amount of change has taken place in my GLOBE Study Site between the years of the two images?

Feel free to start with as little or as much data collection as is comfortable. One Land Cover Sample Site or monitoring leaf growth forone season is a start. Adding another land cover sample site or comparing timing of budburst or leaf growth from previous years can engage students in the process. If you and your students are ready to explore the area surrounding your school, begin the *Biosphere Investigation*!

Protocols at a Glance

Protocol	Procedures	Location	Frequency	Equipment
Land Cover Sample Site	MUC, latitude, longitude, elevation, photographs	In a 90 m x 90 m homogeneous area	Once for every new site during peak growing season, or more frequently in sites of your choosing	MUC Field Guide or MUC System Table and MUC Glossary of Terms, GPS, camera, compass, biometry equipment
Biometry	Canopy cover, ground cover, tree, shrub and graminoid height, tree circumference, graminoid biomass	At Land Cover Sample Sites	To determine MUC or to supplement the observations at a site	Densiometer, clinometer, measuring tapes, Vegetation Field Guides, grass clippers, MUC Field Guide or MUC System Table and MUC Glossary of Terms, GPS, camera, compass
Fire Fuels	Tree, shrub and herbaceous cover and height; count of different sizes of downed woody fuel types	Land cover sample site (a 90 m x 90 m homogeneous area)	Once for each new site	GPS, camera, compass, biometry equipment
Green-Up	latitude, longitude, elevation, photographs, dates of budburst, leaf growth (mm)	Phenology site near school	Twice a week beginning two weeks prior to the anticipated start of budburst	GPS, camera, compass, metric ruler
Green-Down	latitude, longitude, elevation, photographs, dates of color change	Phenology site near school	Twice a week beginning two weeks prior to anticipated color change	GPS, camera, compass, GLOBE Plant Color Guide
Ruby-throated Hummingbird	latitude, longitude, elevation, photographs, dates of feeding and nesting	Phenology site, near flowers or feeder	**Spring:** Daily until first sighting; **Autumn:** Daily until last sighting; **feeder/Flower visits:** twice a week; **Nesting behavior:** daily if possible	GPS, camera, compass, Hummingbird feeder and food or flowers, Bird identification guide
Phenological Gardens	latitude, longitude, elevation, photographs, identification of phenophases, soil characterization and soil pH	Phenology site near school	Daily for each plant variety before leaf growth and blooming starts and during the blooming stages. Two or three times a week in between blooms	GPS, camera, compass, tape measure, materials for soil field characterization and soil pH
Lilac Phenology	latitude, longitude, elevation, photographs, identification of phenophases	Phenology site near school	Daily beginning in Spring, to the end of bloom	GPS, camera, compass,materials for planting

Protocols at a Glance

Protocol	Procedures	Location	Frequency	Equipment
Lilac Phenology	latitude, longitude, elevation, photographs, identification of phenophases	Phenology site near school	Daily beginning in Spring, to the end of bloom	GPS, camera, compass,materials for planting
Arctic Bird Migration Monitoring	latitude, longitude, elevation, bird identification	near school	Every other day beginning 2 weeks prior to expected arrival time until few or none of the selected bird species are seen	GPS, Compass, Binoculars, Bird identification book
Seaweed Reproductive Phenology	latitude, longitude, elevation, identify reproductive stages	Beach or other access zone to ocean	Once a month for four months in a row during low tides	GPS, compass, seaweed repruductive stages photos, clinometer, meter sticks
Site Set-up	Latitude, Longitude, elevation, pacing	Carbon Cycle Sample Site	Once per Sample Site	Compass, flags, camera,GPS/phone
Cycle Tree Mapping	Tree location and ID	Carbon Cycle Sample Site	Once per Sample Site	50 m flexible measuring tape, local tree ID guide,compass
Carbon Cycle Tree Circumference	Tree circumference	Carbon Cycle Sample Site	Once per year	Measuring tapes (150-300 cm)
Carbon Cycle Shrubs	Shrub type, shrub height	Carbon Cycle Sample Site	Once per year	Compass, 2-3 m stick marked in centimeters
Carbon Cycle Herbacious	Herbaceous biomass	Carbon Cycle Sample Site	Once per year	OUTSIDE: beanbag,blindfold, measuring tape,clippers, small brown paper bags, INSIDE: balance,drying oven (optional)

Suggested Methodology for Land Cover

The following flow diagrams (Figure BIO-I-3, Figure BIO-I-4) present the methodology to conduct the Land Cover portion of the *Biosphere Investigation*. This part of the investigation focuses on determining and mapping the land cover for a particular area, a Biosphere Study Site surrounding your school, and monitoring it for changes over time. This flow diagram is divided into two parts. The first part outlines the land cover data collection methods and the second part shows the land cover mapping and change detection procedures. Italics indicate the protocols and learning activities within the flow diagram. All these measurements can be used to improve our understanding of the cycling of energy, water and chemical elements such as carbon and nitrogen. The land cover maps students make of their Biosphere Study Site and maps of larger areas created by scientists can be used for management, research, and student inquiry. How and where are land cover types changing? Are there differences in soil fertility between the soil under a deciduous forest and a wetland? What happens to the water chemistry when the surrounding land cover changes? These and many other questions are best answered with the help of accurate land cover maps and field measurements.

Data Collection

To begin the Land Cover portion of the *Biosphere Investigation* you need to become familiar with your GLOBE Study Site by examining a Landsat satellite image as well as any other maps or photos of the area that you can obtain. Along with examining the imagery, sites on the ground should be explored to begin to understand the various types of land cover within the 15 km x 15 km GLOBE Study Site. Once you gain some familiarity with the GLOBE Study Site, select homogeneous areas (the same land cover type throughout) for collecting Land Cover Sample Site data. Before going to sites, students should have an

Figure BIO-I-3

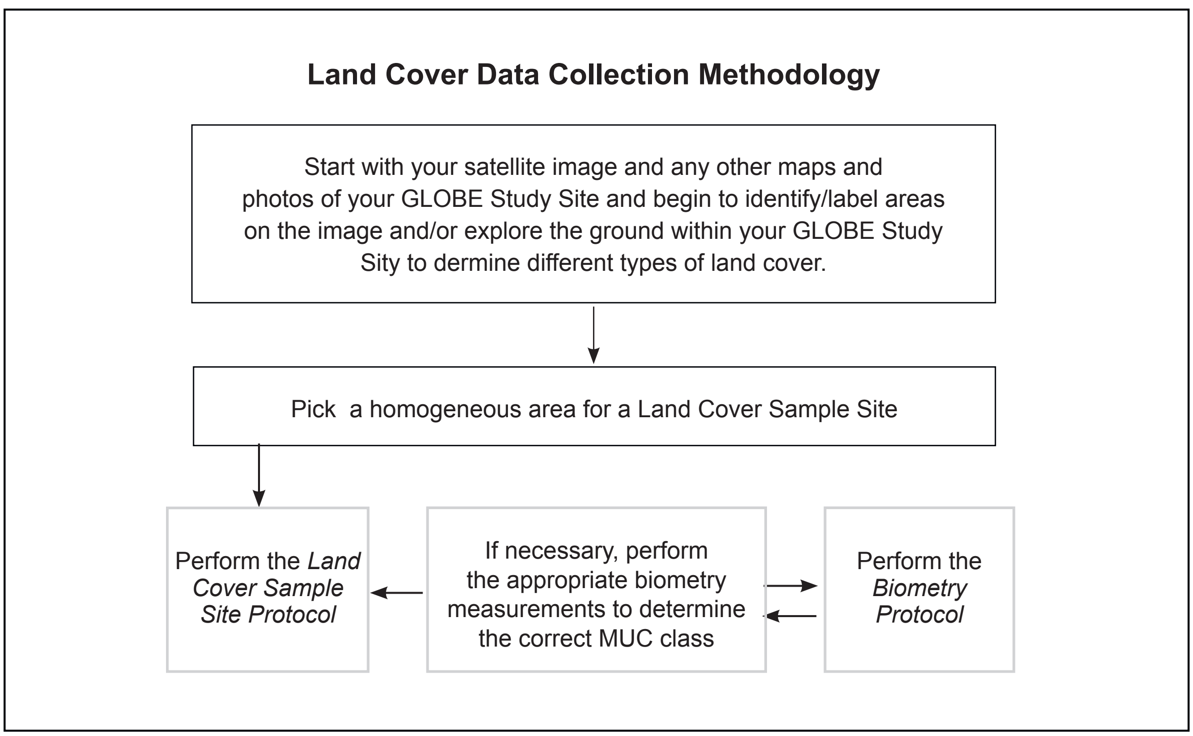
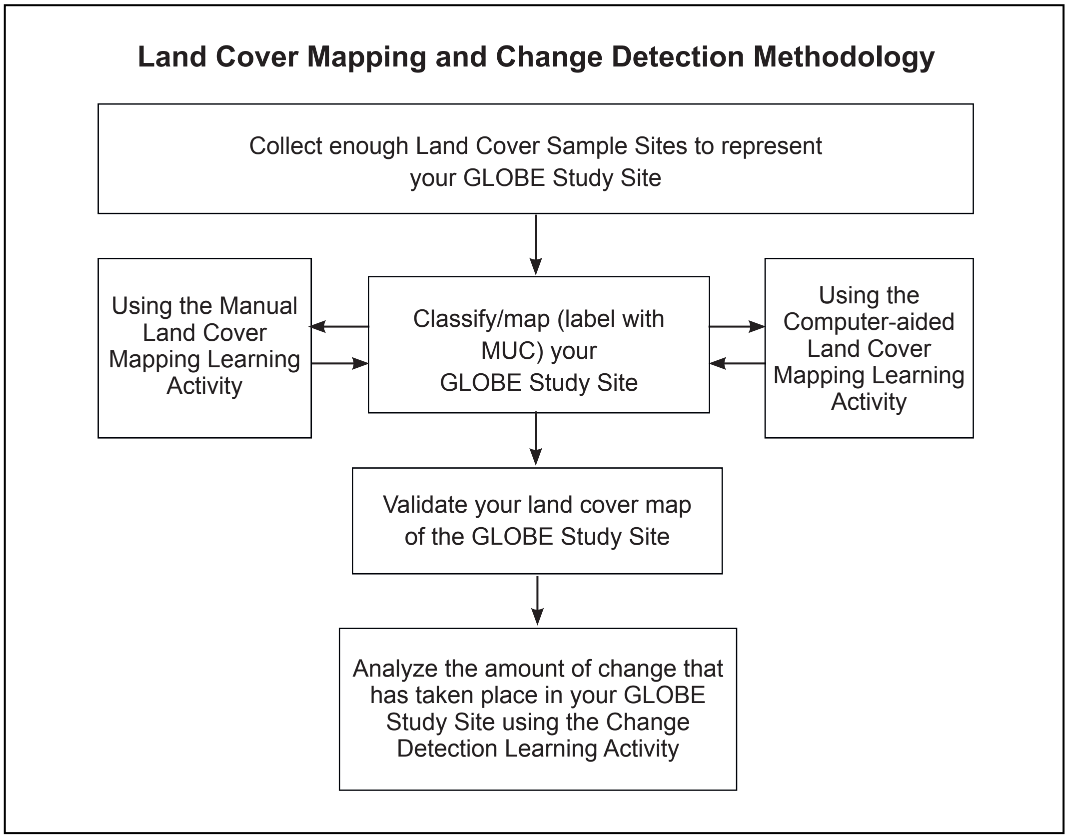


Figure BIO-I-4



understanding of the land cover classification system used in GLOBE, the MUC System, and how the biometry measurements can be used to help determine the MUC class. Also, be sure that you have all the necessary equipment to carry out the field measurements. You will make a few key pieces of equipment yourself following directions in the *Investigation Instruments* section of this chapter. You should also have enough copies of the *Field Guides* for taking the measurements (found in the *Protocols*) and the corresponding *Data Sheets* (found in the *Appendix*). Students who practice the biometry measurements before field collection carry out the measurements more efficiently and accurately in the field. Once a homogeneous sample site has been chosen, the MUC System understood, you have constructed your instruments, made the necessary copies of field guides and *data sheets*, and practiced the *Biometry Protocol*, you are ready to establish a Land Cover Sample Site.

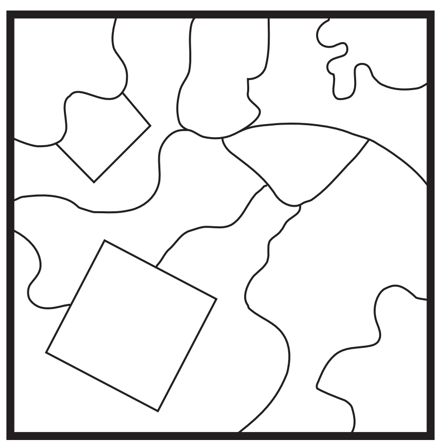
It is highly desirable for you and your students to collect data for several Land Cover Sample Sites in each of the major types of land cover identified within your GLOBE Study Site. You should also collect as much biometry data as needed at each Land Cover Sample Site to accurately classify the site using the MUC System. Start with the most common types of land cover, and continue to add sample sites until you have collected data for as many of the land cover types as you can. Doing this investigation is made easier if your students have a GPS receiver with them when they are at each site. This way, they do not have to return to the site later, find the center and take measurements on another trip.

Biometry data should be collected at Land Cover Sample Sites that are visited once in order to determine the MUC class. The amount of biometry data collected will vary but you can always collect more data to supplement the information about the site. It is desirable to take the full set of biometry measurements at one site that is representative of each forest, woodland and graminoid (grassland) MUC class found in your area. Biometry data can also be collected at sites that you visit more frequently. Some schools choose one site which they visit every year at the same time of year to record changes in biometry over time. Other schools choose to visit a single site twice a year in order to track seasonal changes. Often, their visits will correspond to the times of peak foliage and minimum foliage (drought or winter season). In summary, at a minimum, collect biometry measurements at each site to help you determine the MUC class. The maximum amount of data you collect is your class' decision and should be based on what kind of changes you are monitoring in your site. All land cover data collected accurately by GLOBE students will be useful. GLOBE scientists recognize that logistics and educational concerns will usually dictate what land cover measurements are taken.

Land Cover Sample Sites are important for validating the accuracy of land cover type maps, which is a key scientific objective of this investigation. It is recognized, however, that it will take time, perhaps several successive years, to accumulate a set of Land Cover Sample Sites representative of each important type of land cover within your GLOBE Study Site. You may want to assign a land cover type to each of several student teams, so that no two teams are working in the same type of land cover and as many data are collected as possible.

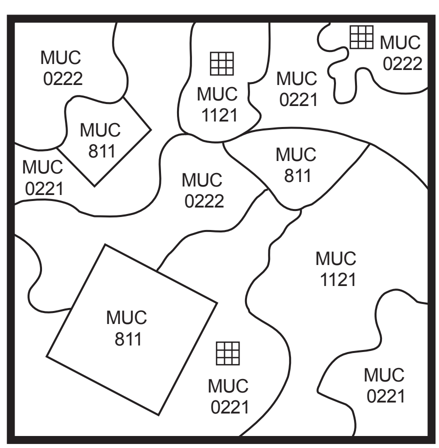
Figure BIO-I-5: Diagram of Accuracy Assessment Process

Step 1: Manual or Computer-aided Land Cover Mapping



The Landsat image of your GLOBE Study Site is divided into areas of similar land cover types manually or using MultiSpec.

Step 2: Assign MUC Classes to Areas (Clusters)

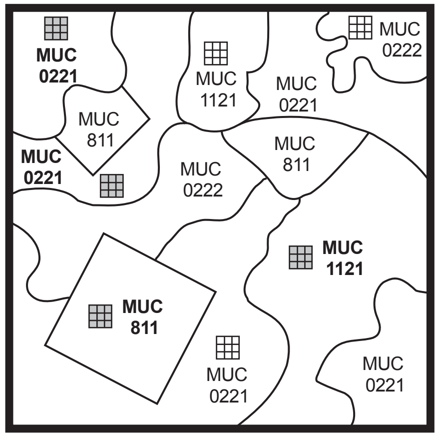


For each area outlined by manual mapping or computer-aided mapping using MultiSpec, assign a MUC class using students' knowledge of the area and data collected from Land Cover Sample Sites.

⊞ Land Cover Sample Sites

Figure BIO-I-5: Diagram of Accuracy Assessment Process (continued)

Step 3: Collect Validation Data

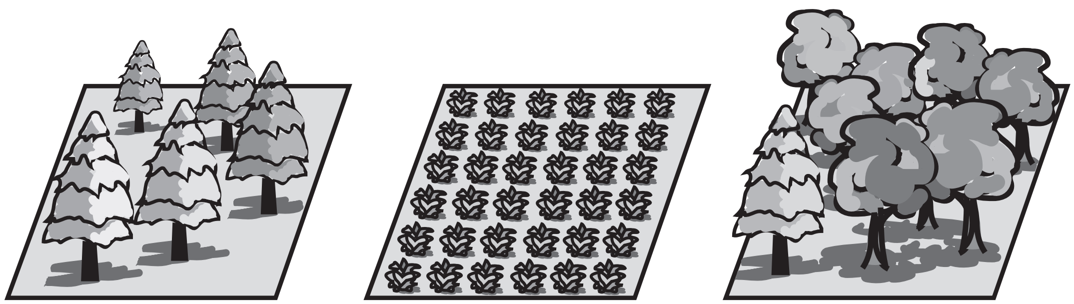


Once the land cover map is made, collect validation data at additional Land Cover Sample Sites to assess the accuracy of the classified map.

Over time, observe and measure as many validation sites as possible for each of the land cover types in your area.

Land Cover Sample Sites

Validation Land Cover Sample Sites



Step 4: Assess Map Accuracy

Validation Data

Student Map Classification	MUC 0221	MUC 0222	MUC 1121	MUC 811	Row Totals
MUC 0221	I				1
MUC 0222	I				1
MUC 1121			I		1
MUC 811				I	1
Column Totals	2	0	1	1	4

Overall Accuracy = 3/4 x 100 = 75%

Compile the data on the Accuracy Assessment Work Sheet and use the Work Sheet to build a difference/error matrix to compare the Student Map Classification data to the Validation Data from Land Cover Sample Sites.

From the difference/error matrix, calculate accuracy assessment percentages to assess how accurate your land cover type map is.

The Mapping and Accuracy Assessment Process

Figures BIO-I-5 show the logical steps in producing a land cover type map and assessing its accuracy. There are two options for creating a map. The first is to create it by hand from prints of a satellite image following the Manual Land Cover Mapping Learning Activity. The second is to create it electronically from a digital version of the satellite image using the MultiSpec software and following the Computer-aided Land Cover Mapping Learning Activity. You are encouraged to begin collecting data for Land Cover Sample Sites before you begin this mapping process. Student observations of individual sites are valuable even if your students do not complete a land cover map of their own because scientists and students in future years or neighboring schools can use your data in their own land cover type maps.

The process is as follows: (1) Collect representative Land Cover Sample Sites of various land cover types. Collect as many of these as you can. Try to collect at least one representative Sample Site for each land cover type that you observe in your Study Site. (2) Create a land cover type map using the MUC System. Use either the Manual Land Cover Mapping Learning Activity and the hard copy prints of a Landsat imagery or the Computer-aided Land Cover Mapping Learning Activity with the MultiSpec image processing software and a digital image. You can also have your students use both of these learning activities and make comparisons of the two maps. Use the sites you collected to assist you in making the map. (3) Collect additional Land Cover Sample Sites. Collect as many of these as you can. (4) Assess the accuracy of your land cover type map by comparing the map you created to the Land Cover Sample Sites collected in your Study Site that students have measured and not used to create their map.

Suggested Methodology for Carbon Cycle

GLOBE Carbon Cycle is focused on bringing the most cutting-edge research and research techniques in the field of terrestrial ecosystem carbon cycling into the classroom. It uses a systems-thinking approach to gain a foundation in the carbon cycle and its relation to climate and energy. The materials incorporate a diverse set of activities geared toward upper-middle and high school students, including:

- **Introductory Learning Activities**: Hands-on activities that use a systems thinking approach to understanding the global carbon cycle, while introducing important concepts such as pools, fluxes, and equilibrium.
- **Plant-A-Plant Experiments**: Hands-on cultivation experiments for the classroom, with options for structured, guided, or open levels of inquiry.
- **Protocols and Field Learning Activities**: Skills designed to help you collect and analyze data to determine the biomass and carbon storage in the vegetation near your school, including guides for uploading and interpreting data. Protocols can be done in Standard (homogeneous vegetation) or Non-standard (school yard, city park) sites.
- **Modeling**: Computer models (at varying levels of complexity) to help you predict the change in biomass and carbon storage over time, and give students the opportunity to use an important scientific tool.
- **Teacher Support**: Comprehensive eTraining modules; NGSS-correlated materials; ready-to-use assessment materials; and background information on carbon, systems, models, and inquiry teaching.

Please see the following flowcharts to determine the best way to use the GLOBE Carbon Cycle materials in your classroom:

Carbon Cycle Introductory Materials Flowchart

Carbon Cycle Flowchart with Standard Site Protocols

Carbon Cycle Flowchart with Non- Standard Site Protocols

Implementation Considerations

Sequencing, Interconnections, and Interdependence of Learning Activities and Protocols

In order to report data for the main protocol, the *Land Cover Sample Site Protocol*, students must be able to carry out the *Biometry Protocol* and accurately record the location of sites (latitude, longitude and elevation) using a GPS receiver. In addition, students must be able to use MUC to classify land cover, pace accurately, use a compass, and make and know how to use a densiometer and clinometer correctly. It is highly recommended that you use the order below to effectively implement the Land Cover/Biology portion of the *Biosphere Investigation*. Note that *Pre-Protocol Learning Activities* are necessary to ensure that students are familiar with the key concepts and skills required to carry out the protocols.

#	Learning Activity or Protocol	Sequencing recommendations
1	*Getting to Know Your Satellite Imagery and GLOBE Study Site Learning Activity*	Investigation Preparation, Strongly Recommended
2	Pacing and Compass (See *Investigation Instruments*)	Protocol Preparation
3	*GPS Protocol* (See *GPS Chapter*)	Imbedded Protocol
4	Make and practice using a *Clinometer* and *Densiometer*, learn how to use and read a *Tape Measure* (See *Investigation Instruments*)	Protocol Preparation
5	*Site-Seeing Learning Activity*	Recommended
6	*Biometry Protocol*	Imbedded Protocol
7	*Leaf Classification Learning Activity*	Pre-Protocol, Strongly Recommended
8	Practice with the *MUC System*	Imbedded Skill
With the above skills, students should be able to carry out the *Land Cover Sample Site Protocol*.		
9	*Odyssey of the Eyes Learning Activity*	Pre-Learning Activity, Strongly Recommended
10	*Manual Classification: A Tutorial for Beverly, MA Image* OR *Introduction to the MultiSpec Program and the Unsupervised Clustering Tutorial*	Learning Activity Prep, Strongly Recommended
After doing at least one *Land Cover Sample Site Protocol*, students should carry out either the *Manual Land Cover Mapping Learning Activity* or *Computer-aided Land Cover Mapping Learning Activity*.		
11	Collect many more Land Cover Sample Site data	
12	Bird Beak Accuracy Assessment Learning Activity	Pre-Learning Activity, Strongly Recommended
13	Carry out an Accuracy Assessment on the Land Cover Type Maps	
14	Change Detection Tutorial	Learning Activity Prep, Strongly Recommended
15	Change Detection Learning Activity	Culmination activity of Land Cover portion of Biosphere Investigation
16	Discovery Area Learning Activity	Follow-up Learning Activity
17	Using GLOBE Data to Analyze Land Cover Learning Activity	Follow-up Learning Activity