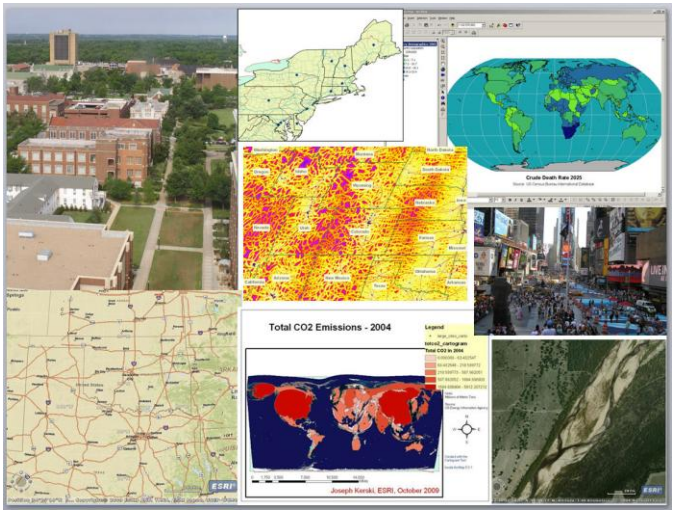
Connecting GIS to Environmental Education



Analyzing environmental phenomena, patterns, and processes is enhanced through the use of spatial analysis with GIS.

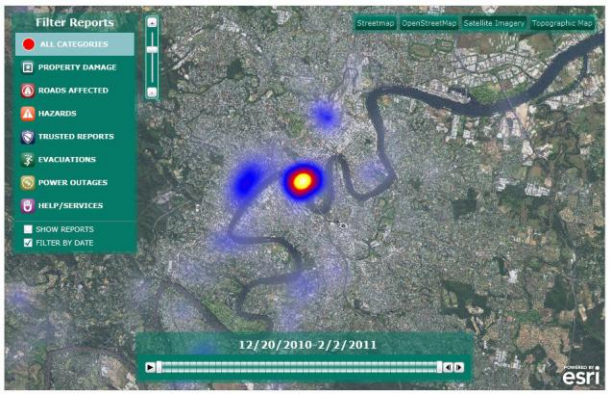
10 Linkages Between GIS and Environmental Education

GIS and environmental education are inextricably linked. How can environmental education be more effectively taught and learned using GIS? Let's explore 10 ways.

First, every environmental issue from pollution to habitat to biodiversity and beyond has a geographic component. Consider the major environmental issues of our 21st Century world: Coastal erosion, air, soil, and water pollution, urbanization, desertification, habitat loss, invasive species, and deforestation, just to name a few. Each of these issues occurs somewhere, and usually in multiple locations. Each occurs at specific scales and sometimes at multiple scales. For example, climate change is a global phenomenon that also impacts local weather and crop yields. Each phenomenon exhibits a spatial pattern in its source and in its diffusion. Each affects multiple facets of the human and physical environment. Therefore, the geographic perspective is key to understanding those issues, and GIS provides a rich toolset in which to use the geographic perspective. GIS allows for the multiple variables necessary in environmental studies to be used as map and image layers, at multiple scales, able to be analyzed in two dimensions and in three dimensions.

Let's examine one environmental issue in more detail to illustrate these points in action—coastal erosion. Coastal erosion occurs as a natural process of wave action on coastlines. However, it can be exacerbated by human practices of land use and development, and it has caused loss of soil, loss of entire tracts of land, damage to property, degradation of land and water animal and fish habitat, and loss of human lives. It is not only tied to the practices of human land use near and on coasts ranging from agriculture to residential and commercial development and the construction of jetties, but also is tied to the underlying soil type, landforms, and climate, as well as changes to sea level over time. Some of these processes occur on a local scale, some occur on a regional scale, and some, such as sea level change, are tied to global scale phenomena. Thus, soil erosion is affected by land use, land cover, elevation, ocean currents, local weather, long-term climate, and other processes. Each of these processes operates differently around the world, differently in local areas, and each is affected by and affects other processes. To understand the interaction of these processes requires a firm foundation in the principles of physical geography and cultural geography, the geographic perspective, and skills in using GIS. The same can be said for thousands of other environmental issues: Environmental studies are enhanced by geographic principles, the geographic perspective, and GIS.

Second, not only are environmental studies enhanced by GIS, but conversely, the use of GIS is enhanced by a firm grounding in environmental studies. This grounding provides the framework by which questions can be formulated and problems designed. Asking questions is the first part of scientific inquiry: It forms the basis for knowing what types of environmental data to collect, what data to analyze, and what decisions to make. The GIS does not ask the questions. Rather, it is the user that has a firm foundation in understanding climate, ocean currents, seasons, soils, biomes, pollution, human health, and the past and present environmental legacy of the planet who asks the questions. The environment has shaped humans, and humans have shaped the environment. Understanding this interaction is fundamental to asking questions and solving problems with GIS.

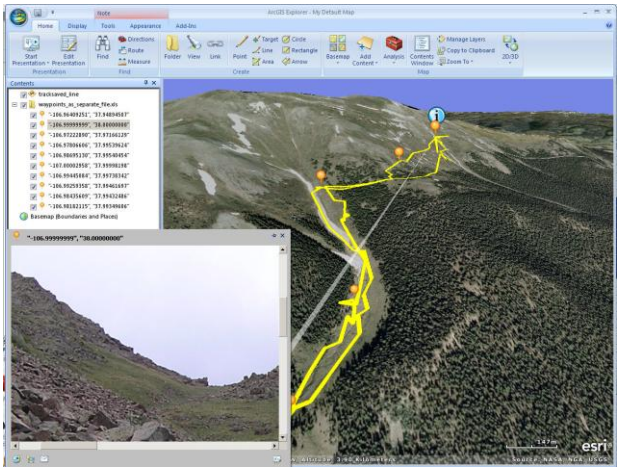


Third, one of environmental studies' central themes is examining the interaction between humans and the environment. How does the environment, through such characteristics as daily weather and long-term climate, native plants and animals, landforms, the availability of water, local and regional natural hazards, and the type of predominant soils, affect people? How do these factors affect the growth of cities, sustainable agriculture, water quality and quantity, tourism, culture, and population growth and change? Conversely, how do humans affect their environment? Humans represent the largest change agent on our planet today, affecting their local and regional environments, and in the past 200 years, their impacts have increasingly been noticeable on a global scale. These impacts include the clearing of forests and other natural vegetation for agriculture, urbanization, water-related projects from the building of dams to the widening and deepening of river channels to groundwater withdrawals, burning of fossil fuels, building seawalls, mining, construction, and in thousands of other ways. Environmental issues are bound up in scale, in place, in cultural practices, in the biosphere, atmosphere, lithosphere, hydrosphere, and anthrosphere. Thus, to use GIS effectively to examine human-environment interaction requires a firm foundation in environmental content, skills, and the geographic perspective.

Fourth, studying environmental issues with GIS lends relevancy and real-world contexts to these issues. The central themes that environmental scientists have studied for years have in recent decades become topics on daily newscasts. Pollution, traffic, habitat loss, climate change, erosion, and many others have caused some to claim that the 21st Century is indeed the "Environmental Century." In recent years, three aspects of environmental concerns have become evident. First, environmental concerns have become global issues. Second, environmental issues increasingly impact the everyday lives of everyone on the planet. Third, environmental issues are complex and require a different kind of thinking, a thinking that not only crosses borders of countries or ecoregions, but also that crosses traditional disciplinary boundaries. Geography and environmental studies provide the means by which students can develop that kind of thinking that will help them make sense of these issues on multiple levels. For students to understand ways to live in harmony with the environment, they need to understand the connections with their own actions and that of their fellow human beings to global processes, and therefore, they need to understand the principles of those processes. These processes include such

diverse topics as the carbon cycle, global trade, earth-sun relationships, and climate. Because environmental studies have became more quantitative, experimental, and analytical during the past century, GIS is the perfect tool in which to study environmental processes through databases, maps, and spatial statistics.

Fifth, teaching about sustainable practices in agriculture, urban development, ecotourism, energy, or any other field using GIS requires a grounding in core concepts in ecology and geography. It is not enough to know only *content*, because environmental phenomena interact, move, and change. Therefore, relationships and processes are critical to understanding. GIS can foster each of the Center for Ecoliteracy's (http://www.ecoliteracy.org) six core ecological concepts: networks, nested systems, cycles, flows, development, and dynamic balance. GIS allows variables to be input, modeled, and modified, so that the dynamics of environmental processes can be studied. Hungerford and Volk (1991) defined nine key ecological concepts that they said were necessary for environmental education programs, including individuals and populations, interactions and interdependence, environmental influences and limiting factors, energy flow and nutrient cycling, community and ecosystem concepts, homeostasis, succession, humans as members of ecosystems, and ecological implications of human activities and communities. GIS can enhance the teaching of these concepts. A current NSF-funded project on environmental literacy (NAAEE, 2011) has resulted in a definition that includes four interrelated components—competencies, knowledge, dispositions, and environmentally responsible behavior. By using the same tools used by scientists, GIS aids in the first two of these, and by investigating real issues in their communities and beyond, GIS aids in helping with the last two of these components.



Sixth, students who use GIS in tandem with environmental studies develop key critical thinking skills. These skills include understanding how to carefully evaluate and use data. This is especially critical in assessing environmental data, due to its increasing volume and diversity, and given its often sensitive and politically-charged nature. In addition, "crowdsourced" data is now appearing from "citizen science" initiatives all over the world, where ordinary people collect information on pine beetle infestation, the appearance of monarch butterflies in their community each spring, the date of the first frost, and a host of other data. These data are more frequently being tied to real-world coordinates, mapped, and analyzed. Students and graduates using GIS and who are grounded in environmental studies will be in demand to help make sense of this deluge of incoming data.

Seventh, students immersed in environmental studies at all levels of education can apply geotechnologies to understand environmental issues. Grappling with complex environmental issues requires tools that can handle a large volume and a wide variety of data, so that scenarios can be modeled and patterns can be analyzed. These tools include Geographic Information Systems (GIS),

Remote Sensing, Global Positioning Systems (GPS), and scientific probes and sensors of all kinds that can record a position on the earth's surface as they are collecting data.

Students using these tools can map phenomena and features such as ocean currents, ecoregions, and the location of geothermal energy. They can use the tools to answer such questions as "How does pH vary along this stretch of river, and why?", "How do tree species and tree height change depending on the slope angle and slope direction of the mountain, and why"? "Why do wind speed and direction vary across North America the way they do"? Geotechnologies were created and developed by the geographic community specifically to solve problems. As such, they are key tools used not only by environmental studies students, but also by hundreds of thousands of practicing environmental scientists around the world on a daily basis.

Students using these tools in the classroom and in the field therefore also gain key skills that will help them secure careers that are in demand in the workforce. Students using these tools are primed for green careers as wildlife biologists, solar energy consultants, city planners, environmental consultants, landscape architects, and in hundreds of other positions. GIS was a "green" tool long before "green" was popular. GIS is used on a daily basis to benefit the environment, through protecting elephant habitat in Africa to planning urban greenways in the local community, and thousands of other ways in between.

Eighth, students who are well grounded in the spatial perspective through GIS are better able to, upon graduation, use data at a variety of scales, in a variety of contexts, think systematically and holistically, use quantitative and qualitative approaches to solve problems. In short, these graduates are better decision makers. Students engaged in GIS and environmental studies make heavy use of the geographic inquiry process. This involves asking geographic questions, acquiring geographic resources, analyzing geographic data, assessing and making decisions from resulting geographic information, and acting on that geographic information. This often leads to additional geographic questions, and the cycle continues. But key is that studying geography and environmental studies is an applied science—it leads to action.

Ninth, GIS through environmental studies adheres to the tenet that learning is often most effective when it takes place outdoors. Fieldwork has such a long and rich history within environmental studies that it is almost like stating the obvious. However, in a world where outdoor education is often cut due to budgetary constraints, and when a frighteningly large proportion of the population has almost no connection with the outdoors, it bears emphasizing. In environmental studies, the "offices" of many educators actually are in the field—in nature centers, museums, parks, and wildlife reserves. In the field, students can collect data on a myriad of phenomena, such as tree species, water quality, weather, soil chemistry, and more. In so doing, they gain a better understanding of processes, scale, and the

environment in a way that they might not be able to do in the classroom. They can sketch, record video, take photographs, or simply use their five senses.

Beyond data collection, they develop an appreciation for the balance of nature, or the "unbalance," depending on where they are, and the connectedness of the hydrosphere, atmosphere, lithosphere, and biosphere. Studies show that if students do not receive repeated and deep immersion in natural places while young, they will not value nor appreciate natural places nor their associated environmental processes or issues as adult decision-makers. And that leads to the final point.

Tenth, given the widespread environmental concerns faced by the modern world, it is imperative that students study and understand about these issues not only to equip them for life in the 21st Century, but to ensure that we emerge at the end of the 21st Century in a sustainable way. How can we expect decision-makers to care about the planet unless they have learned about the planet as students? And how can they learn about the planet unless they study the environment and use GIS in doing so as students?

Resources Connecting GIS to Environmental Education

Esri develops and connects educators to resources that enable the effective use of GIS in environmental education. Many of these resources, such as lessons, data sets, and tools, can be accessed via the Esri Education Community (http://edcommunity.esri.com). Let's explore just a few of these resources.

Wind Energy Activities

Five curricular activities have been created that use the spatial perspective and GIS to investigate wind and wind energy from a continental to a local scale. Four of the activities use a web-based GIS (ArcGIS Online) and one uses ArcGIS desktop version 10. One might say these activities are "wind-driven!"

- Analyzing Current Wind Speed and Direction in North America uses ArcGIS Online as a tool for examining the spatial or geographic dimensions of current wind speed and direction in North America. Compare your own data gathered at your location to the online current wind speed and direction. Consider why and where winds blow.
- Siting a Wind Farm in Indiana uses ArcGIS Online for siting a wind farm in Indiana. Use variables such as proximity to existing powerlines, population density, and other criteria to determine the ideal site for a wind farm.
- Exploring the San Gorgonio Wind Farm uses ArcGIS Online for exploring the famous, enormous San Gorgonio Wind Farm in California. Consider why terrain, wind speed and direction, and population base make this the ideal place for a wind farm through analyzing local maps and a

video filmed on site. The activity ends by inviting you to investigate a different wind farm and create a map, telling its story using ArcGIS Online.

- Siting a Wind Turbine on Your School Campus uses ArcGIS Online as a tool for siting a wind turbine on a typical school campus. Consider relief, proximity to buildings, wind speed, local access, and other variables, first by examining Platte Valley High School in Colorado, and then your own campus.
- Siting wind farms in Colorado with GIS uses ArcGIS version 10 as your primary investigative tool, considering the location of cities, the Continental Divide, highways, rivers, counties, wind speed and power, land use, and elevation. Data layers are from Esri, the National Renewable Energy Laboratory, and the Colorado Department of Transportation.

All of the lessons reside on the ArcLessons library, on http://edcommunity.esri.com/arclessons. Educators can use these activities to encourage spatial thinking, to teach and learn about wind and wind energy, and to foster GIS skills.

North American Environmental Atlas

Esri also promotes and connects educators with data and maps that are useful in using GIS for environmental education. One of the most useful continent-wide spatial data environmental-related resources is from the North American Environmental Atlas (http://www.cec.org/atlas). It contains data on watersheds, ecoregions, human impact on protected areas, industrial pollution, wetlands, land cover, conservation areas, and base layers including transportation, waterways, and cities. It also contains layers on 17 species of common conservation concern, such as the Burrowing Owl, the Mountain Plover, and the American Black Bear. The atlas was born from collaboration among the national mapping agencies in Canada, the United States, and Mexico, and through the Commission for Environmental Cooperation. Its goal is to provide a foundation to analyze the status of environmental conditions and identify trends across the whole continent.

The atlas is useful because of its rich content, the fact that it is comprised of public domain data, and because you can use it in three different ways. First, you may order up to five free paper wall-sized maps from the link on the site. Second, the content is offered as a Web GIS, meaning that you can examine the data interactively with just a web browser, made possible by ArcGIS Server running behind the scenes. What is the relationship between grasslands, rainfall, and elevation? Third, the data from the site is offered as downloadable shapefiles, layer packages, and map documents, ready for ArcGIS desktop. Metadata files are readily available and you can use the web GIS viewer for previewing the data before downloading. Why download the data if you can analyze it online? Both methods are valid approaches to helping students think spatially, but by downloading the data and using it inside ArcGIS

desktop, you can dig deeper, analyzing the patterns across space, time, and with spatial statistical techniques. For example, you can assess how much burrowing owl habitat is within 10 kilometers of a pollutant release facility. I also like the atlas because it does not ignore the oceans—marine ecoregions, protected areas, and marine vessel emissions are all included.

GPS to GIS Video Series

A series of videos on the Esri Education Team's YouTube Channel and on a geography channel describes the process of gathering field data with GPS and mapping and analyzing it with GIS in educational contexts. The videos feature explanations and demonstrations not only on the technical procedures involved with gathering data on locations and characteristics of data and then analyzing its spatial patterns, but also the pedagogical advantages to using these technologies within the context of spatial thinking in instruction. In short, they focus not only the "hows", but also the "whys".

Topics covered are suitable for all levels of education, formal and informal, and can be used in geography and beyond, in environmental studies to geography, history, mathematics, and earth and biological sciences. The videos span multiple tools, from the Minnesota DNR Garmin program to ArcGIS desktop, ArcGIS Explorer, ArcGIS Online, and ArcGIS Explorer Online. The videos span multiple methodologies and discuss the merits of each. For example, one discussion illustrates the advantages of keying in field data and coordinates versus cabling the information to a computer, and the advantages of linking maps to multimedia taken from a standard camera versus that taken from a smartphone. Embedded throughout the series are issues of data and project management, scale, accuracy, precision, metadata, and appropriateness. At present, 25 titles exist in the series with more to be added in the future. These include considerations before embarking on a field data collection project, the difference between GPS tracks and waypoints, transferring GPS-gathered coordinates and field-collected data to the GIS, mapping and analyzing field data with ArcGIS Online, using a smartphone for location, photographs, and video in gathering and mapping data, drawing with GPS, and much more. Educators can use these videos, and more importantly, the methodologies presented here, in their instruction.

The Importance of Outdoor Education in Studying the Environment

We laugh at the scene in the movie "Vacation" when Chevy Chase's family finally arrives at the rim of the Grand Canyon, only to snap a few photos for a minute before getting back into the car and driving to their next destination: "OK—next?" Yet how much of our fieldwork is brief and limited to just a few of the five senses? Events such as Earth Day and Geography Awareness Week provide an annual reminder to all of us that fieldwork is critical to what the geography education community believes in, advocates, and analyzes. Nowadays, we have so many map, video, and data sources along with GIS tools at our

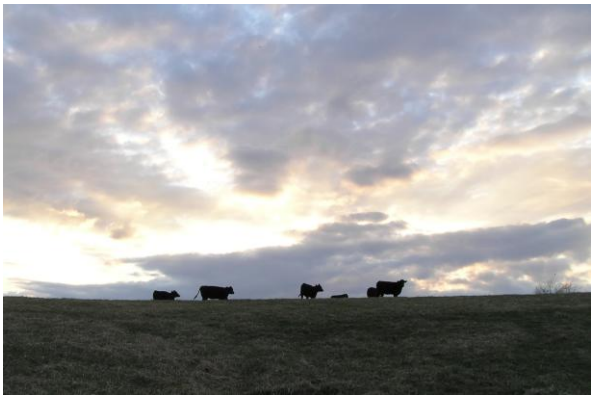
fingertips that it is tempting to think we can “get by” without doing any fieldwork. Indeed, in these days of educational funding constraints when fieldwork involves high costs, permissions, and effort, these resources are extremely welcome and valued.

The importance of fieldwork goes far beyond the environmental or geography education communities. Sobel's *Beyond Ecophobia: Reclaiming the Heart in Nature Education* (1996) makes it clear that children are disconnected from the world outdoors, but yet are as never before connected with endangered animals and ecosystems around the globe through electronic media. He states that essential to helping students to understand environmental issues in distant lands is to cultivate connections to the local environment by teaching about local systems. "What's important is that children have an opportunity to bond with the natural world, to learn to love it, before being asked to heal its wounds." This can be done through his stages of empathy, exploration, and social action. His statements such as “Authentic environmental commitment emerges out of firsthand experiences with real places on a small, manageable scale" are expanded in his book *Place-Based Education: Connecting Classrooms and Communities*. These ideas were brought to the attention of additional educators and the general public by Louv in his compelling book, *Last Child in the Woods* (2005).

Even if students cannot get away from campus, they can still collect data right on their own school grounds. Dr Broda’s book series starting with *SchoolYard Enhanced Learning* provides excellent ideas on how to do just that. To support your continued advocacy for fieldwork in your own educational institution, we have created a video entitled "Why is fieldwork important?"

Using these resources, educators can make every day an “Earth Day” in terms of exciting their students about the importance of observing the world around them.

Collaborations to Foster Environmental Education With GIS



To better enable geography and environmental studies to be promoted, sustained, and promoted in the educational system, Esri seeks to partner with other organizations with similar philosophies and goals. Forming stronger relationships with organizations such as the North American Association for Environmental Education (http://www.naaee.net/) are “natural” fits! The NAAEE has been promoting and supporting environmental education for over 40 years, and contains a network of passionate and experienced environmental educators in a wide variety of settings. Esri has discussed ways that we could work on joint professional development and curriculum development opportunities for educator and look forward to further collaborations with the NAAEE.

Esri works closely with other organizations as well to promote environmental education with GIS. We make use of the documents on the Place Based Education Initiative, and promote the use of probes,

GPS, and other mobile devices to provide primary data to map and analyze within a GIS environment. For years, we have worked with the American Geological Institute on Earth Science Week and with those promoting "No Child Left Inside" initiatives.

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