The Urban Tree Project

Using geographic information systems to determine the ecological value of neighborhood trees

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Geospatial technologies have emerged over the last 15 years as one of the key tools used by environmental scientists (NRC 2006). In fact, educators have recognized that coupling geospatial technologies with environmental science topics and scientific datasets opens the door to local and regional scientific investigations (McInerney 2006). Over the last three years, we have been working to provide tools, curriculum, and resources that allow students to learn science through authentic inquiries using their own scientific data. In this article, we describe the use of geographic information system (GIS) technologies and computer modeling to engage students in determining the economic and ecological value of trees in their neighborhoods.

The GIS project

Our Urban Tree Project is a two- to three-week project that can be implemented in high school environmental science, urban ecology, or environmental technology courses. The project is built around three premises: First, students often do not understand or appreciate the ecological services that trees provide beyond oxygen production and the removal of carbon dioxide from the atmosphere. Second, this project capitalizes on the increased recognition that city street trees have significant ecological impacts and that they play a role in the fight against climate change (Donovan and Butry 2009). Third, GIS has become an indispensable tool for geoscientific exploration, commerce,

and decision making in environmental and social sciences (NRC 2006).

Regardless of the application, geographically related data can be input and prepared in a GIS in such a way that students can visualize the specific data of interest, or combine data to produce value-added information that may help answer a specific problem. Through this problem-solving process, students engage in the same practices as urban ecologists and city planners.

The urban street tree inventory is conducted using ArcView and CITYgreen—an ArcView extension developed by American Forests. ArcView, developed by the Environmental Systems Research Institute (ESRI), is a software product for visualizing, managing, creating, and analyzing geographic data. Using ArcView, one can understand the geographic context of data and identify relationships and patterns in new ways. CITYgreen allows students—through the use and labeling of satellite images—to link a tree's location to a database of geographic, classification, and health information (see "On the web"). Students can conduct analyses of the economic and ecological benefits provided by urban trees and assign a dollar value to those benefits.


PHOTO COURTESY OF THE URBAN ECOLOGY PROJECT TEAM

Students identify a tulip tree.

Perhaps the most beneficial aspect of CITYgreen is that once students have collected and input their data (or used data from an existing neighborhood street inventory) and conducted an initial baseline analysis, they can then ask "what if" questions involving tree planting or removal. For example, in the city of Boston, there has been significant news coverage of the "Big Dig," in which the city has diverted its major interstates into underground tunnels and converted the reclaimed land into green space. The city is also planting 100,000 trees to increase its tree canopy from 26% to 35%. Using CITYgreen, students can write letters to the city's mayor and request that these trees be planted in particular areas. They can even justify their reasoning with a dollar figure that represents how much the trees will save the city through either pollution or storm-water runoff reduction. CITYgreen allows students to quickly generate findings that are not only relevant to their locality, but are also useful to policy makers and the general public.

Training and software costs

CITYgreen requires ArcView ($500 for a K–12 license for instructional campus use) and all appropriate extensions to run. American Forests provides ArcView for a discounted $200 site license fee (see "On the web"). Those school districts and states across the United States that already have a license for ArcView can download an evaluation version of CITYgreen from the American Forests website. Further, by contributing an approved profile to ESRI's Community Atlas program (see "On the web"), schools can earn a campus license for ArcView. New users can acquire help or find out how to obtain the necessary software from ESRI's geomentor program (see "On the web").

Learning how to use CITYgreen is not difficult, but learning the interface of ArcView can be a challenge. Fortunately, there are a number of opportunities for teachers who are interested in learning how to use ArcView and CITYgreen to implement this project. For example, our project website (see "On the web") provides a series of videos and podcasts that walk users through ArcView and CITYgreen and is coupled with curriculum materials. Our project team also conducts an intensive, hands-on summer program and follow-up training for teachers in the Boston area. There are a number of National Science Foundation–funded projects that focus on the use of GIS as well. The Geospatial Education and Career Center website offers an excellent set of free resources (see "On the web").

The classroom experience

Initial data collection, entry, and analysis

The Urban Tree Project consists of several interrelated phases. In the first phase, a satellite image is obtained and a study site—typically around your school—is identified; most states and cities maintain a GIS database of geospatial images that can be downloaded for free. The next step is to collect data on the trees within that site. Creating a grid of the site and assigning different areas to groups of four or so students allows the class to collect data over much of the study site.

Each student in a group is responsible for collecting certain information about each tree. For example, one student uses a dichotomous key to identify the tree's species; another

FIGURE 1

Student baseline report.

(**Editor's note:** This report was created using CITYgreen software provided by American Forests.)

AMERICAN FORESTS
americanforests.org

CITYgreen
calculating the value of nature

Analysis Report

Baseline Report A

Site Statistics

Analysis Area: Unknown Study Site

Scenario: Current Conditions

Area:

0.01	sq. miles
4.93	acres
2.00	hectares

Landcover Distribution:		Acres
0%	Cropland	0.00
32%	Impervious	1.57
26%	Open Space/Pasture/Meadow	1.27
0%	Shrubs	0.00
3%	Tree Canopy	0.14
43%	Urban Land Use	2.12
0%	Water	0.00

Ecological Benefits

Air Pollution Removal

Air Quality Reference City: Boston

	lbs Removed	Dollar Value
Ozone:	4	$13
Sulfur Dioxide:	1	$1
Nitrogen Dioxide:	3	$8
Particulate Matter:	3	$7
Carbon Monoxide:	0	$0
Total:	**12**	**$29**

Residential Cooling Effects

Average Annual Cooling Cost per Home:		$600.00
Number of Homes:	122	
Savings from Trees:		$713.34
Savings from Roofs:		$0.00
Total Savings:		**$713.34**
Savings per Home:		$5.85
Kilowatt-hours Saved:	7,354.02	
KWHs Saved per Home:	60.28	
Carbon Generation Avoided:	293,887.99	lbs.
Carbon Generation Avoided per Home:	2,408.92	lbs.

Carbon Storage and Sequestration

Age Distribution of Trees:		Mature
Carbon Storage:	6	tons
Carbon Sequestration:	20	pounds/year

Stormwater Control

Average 2-yr, 24-hour Rainfall: 3.50 in.

	Conditions: Current	Conditions: w/o trees*
Curve Number:	85.00	85.00
Runoff (in.):	2.02	2.02

Storage volume needed to mitigate the change in peak flow: 0.00 cu. ft.

Construction cost: $2.00 per cu. ft.

Total **$0.00**

*Replaced by default landcover: Urban: Residential: 0.125ac Lots

Economic Benefit Summary

Annual Air Pollution Removal Savings:	**$29**
Annual Energy Savings:	**$713**
Annual Stormwater Savings*:	**$0**
Total Annual Savings:	**$742**

*Annual Stormwater savings is based on financing over 20 years at 6%

measures the diameter of the tree at breast height (i.e., 1.37 m [4.5 ft.] from the ground); another determines its height using clinometers (an instrument that measures the angle from the ground to the top of the tree, so that height can be determined using trigonometry); and another student collects data on the tree's growing conditions—which entails looking for competing trees or overhead wires. This student also determines the health of the tree and records the group's collected data on the data-collection sheet, which is available on our project website (see "On the web").

Once all of the data has been collected for one tree, the group moves on to another tree, and each student takes on a new data-collection role. It is important to note that during the early stages of this project's implementation, we find that one of the more challenging aspects is not the use of the technology, but rather the identification of tree species. Thus, prior to entering the field for data collection, we allow students to practice identifying trees in the classroom using a dichotomous key and images of tree leaves—or sample leaves—so they can collect data more efficiently once in the field.

After students have finished their data collection, they enter their data into CITYgreen. They then label the other land features in their project file—such as roads, buildings, and grass—and conduct a CITYgreen analysis. This produces a baseline report that details the current ecological value of their trees (Figure 1, p. xx). In studying their report, students evaluate the air pollution, carbon sequestration, residential cooling effects, and storm-water control costs, and learn about the total economic value of their trees.

Asking research questions

After student groups have examined their baseline report, they develop a research question to investigate. Because CITYgreen allows students to become virtual urban planners, there are many questions they can ask (Figure 2). Students can also relabel an area on their satellite image—such as grass or pavement—to become a grove of trees, a building, pavement, or water.

In our class, one student group asked the question, "What is the impact of planting 25 American linden trees near buildings in our study site?" To answer this question, students virtually planted 25 linden trees with 10 cm [4 in.] diameters in CITYgreen, and then ran another analysis to determine the impact of planting trees in these locations. The difference between the initial baseline report and the report with the added trees was not significant.

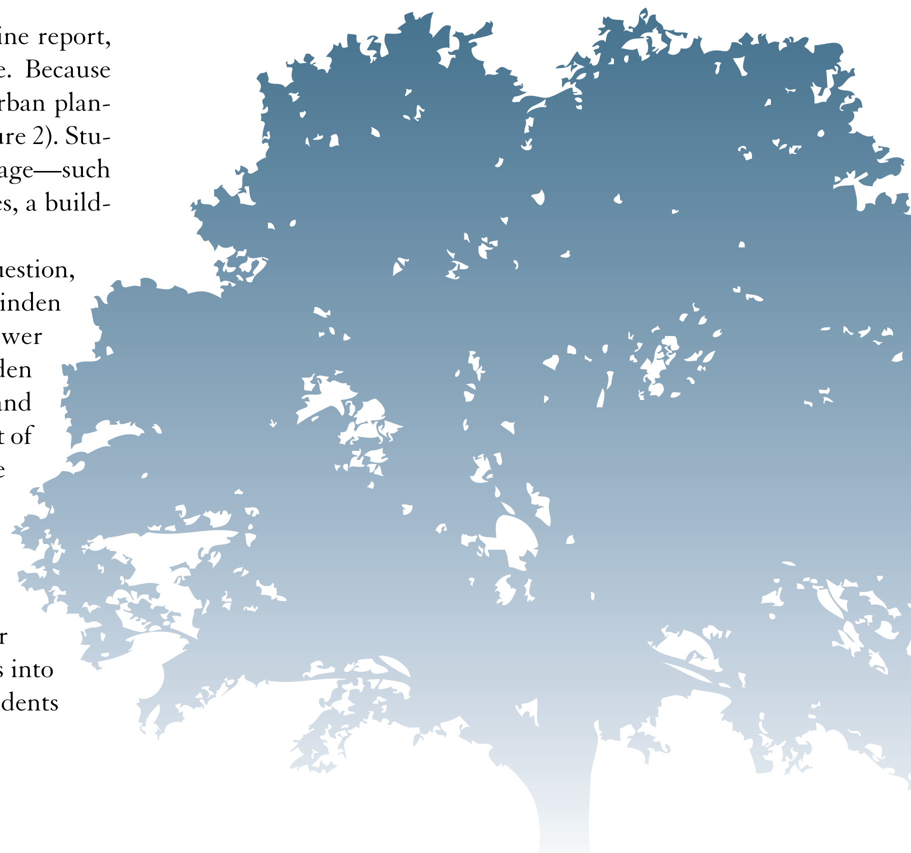
This lack of difference was—at least initially—disappointing for students because they were expecting the trees to have a rather large impact. However, we were able to turn this into a teaching moment: The results encouraged students to think about the size and nature of recently planted trees (namely, that it takes time for them to grow). To evaluate the long-term impact of their change, students conducted a growth analysis using CITYgreen to evaluate the impact of the American linden trees after 20 years. The visual nature of CITYgreen allowed them to see their results and compare the 20-year report to both their baseline report and their initial virtual planting report.

Using these three reports, students quickly compared and contrasted the impact of their changes on the environment. In particular, when examining the amount of carbon generation avoided from the baseline report (Figure 1) to the 20-year report, students noticed that the numbers increased dramatically. This suggests that planting trees near buildings in urban areas is valuable for preventing carbon from entering the

FIGURE 2

Example student research questions.

1. What is the difference between planting American linden trees versus planting pear trees?
2. What is the impact of planting trees in parks, gardens, and other green areas versus planting trees closer to buildings?
3. Should one species of tree or a mix of tree species be planted? Which approach provides the greatest ecological impact?
4. What is the ecological impact of replacing the unused parking areas with green space and trees?
5. What is the impact of turning the field behind our school into a parking lot?



Addressing the Standards (NRC 1996).

Unifying Concepts and Processes (p. 115):

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement

Science as Inquiry (p. 173):

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

atmosphere and that the carbon-avoidance figures are much larger than the amount of carbon sequestered. This finding challenges a typical student misconception regarding climate change—that the best way to slow it down is to simply plant as many trees as possible.

Upon further examination of their reports, students noticed that the amount of carbon sequestered (i.e., the amount of carbon removed from the atmosphere over the course of a year by the trees in their study site) pales in comparison to the amount of carbon avoidance. Carbon avoidance is the prevention of carbon from entering the atmosphere. For example, when a tree shades a building, the amount of electricity needed to cool that building decreases—this then reduces the amount of carbon produced at an electrical power plant. In doing this type of analysis, students learn that the location of their tree plantings can significantly reduce the amount of carbon that enters the atmosphere.

The last phase of the project involves sharing results and writing letters to encourage tree plantings. This enables multiple research questions to be investigated by a single class, allowing students to generate multiple arguments for how to improve their environment. It is this latter phase of the project that is particularly motivating for students because they can recommend changes to policy makers, as shown in the following excerpt from a student letter to the mayor:

> In our analysis of this area, we suggest that the city plant at least 25 trees in the areas along G, H, and Dorchester streets. We have found that planting maple trees where there are none right now will improve the energy efficiency of the housing air conditioners and lead to an annual savings of over $1,500 [per] year in air quality and energy usage…Further by planting the trees there, the city will help to slow global warming because 540,000 lbs. [245,000 kg] of carbon would be prevented from going into the air.

Closing thoughts

When students address real environmental problems, they take pride in doing something with value beyond the classroom and relish the opportunity to observe, implement, and reflect on analytical approaches used by professionals. Collecting and analyzing their own data within the context of data collected by environmental professionals provides a powerful motivational experience for students. They are able to see how creative and elegant uses of technology address long-standing problems or questions within specific disciplines. ■

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On the web

American Forests: *www.americanforests.org*

Boston College Science, Career, Technology, and Education (first author's website): *www.urbanecologyscience.org*

CITYgreen: *www.americanforests.org/productsandpubs/citygreen*

ESRI Community Atlas Program: *www.esri.com/communityatlas*

ESRI Geomentor Program: *www.geomentor.org*

Geospatial Education and Career Center: *http://geoinfo.sdsu.edu/hightech/GISCareerLearningModules_top.htm*

Urban Tree GIS Project: *http://itestlrc.edc.org/inside_itest/maprofile.html*

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