Investigating Urban Trees

Exploring the impact of trees around our school using geospatial technologies

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Trees provide many ecological, aesthetic, safety, and economic benefits to urban environments. One study estimates the economic benefits alone to be worth $394 per tree (Nowak, Crane, and Dwyer 2002). Trees provide many ecological services including habitats and food sources for birds, rodents, and insects. They also reduce energy costs and power plant emissions by providing shade, thus reducing cooling needs in the summer, and wind blocks, reducing heating demands in the winter (Akbari 2002). Trees, more than most plants, remove common pollutants (CO_2, NO_x, SO_2, particulate matter) from the air and sequester carbon dioxide, improving air quality (Endreny et al. 2017). Their role in hydrology is critical; they intercept precipitation and reduce surface runoff into streams and rivers, thereby reducing flooding and erosion (Endreny et al. 2017). Finally, trees also provide aesthetic value to local communities, enhance social interactions, reduce crime rates (Troy, Grove, and O'Neil-Dunne 2012), and provide a pleasant environment for urban day-to-day activities.

We have developed a Trees and Ecological Services (TES) investigation in which students explore the area around their school to identify different types of trees, learn about the environmental and societal benefits that trees provide, and then investigate the relationship between tree distribution and crime in their city. The investigation emphasizes the use of *geospatial* technologies—tools that collect or process location-specific data, typically referenced by a global coordinate pair (latitude and longitude, Universal Transverse Mercator [UTM] coordinates). Geospatial technologies include global positioning systems (GPS), geographic information systems (GIS), and virtual globes (e.g., Google Earth).

We taught the TES investigation over the course of four 90-minute class periods with urban ninth-grade students, 21% of whom were English learners (ELs). For these students, learning with geospatial technologies helped meet their needs by providing an active learning environment with dynamic data visualizations.

Getting started

We designed the lesson using Esri's Collector app for mobile data collection and ArcGIS Online for data analysis, both of which are easy for students to use and freely available to K–12 schools (see "On the web"). If students are not already familiar with Collector and ArcGIS Online, you may want to run a short introductory activity. For example, during the second week of the school year, our students complete a short ecosystem scavenger hunt activity (see "On the web") to become familiar with these technologies. We run the apps on tablets with GPS capability. If your school does not have equivalent devices for data collection, smartphones can be used. (We find that many high school students own smartphones that can be used for data collection.)

The student-collected data are then uploaded and shared into ArcGIS Online (see "On the web"). We developed the ArcGIS Online map to include other freely available data layers derived from public datasets that are displayed with students' collected data and observations. The data layers are displayed in an interactive mapping visualization that includes a suite of tools that students use to manage, query, and analyze the geospatial data.

While our investigation was designed specifically for our city, a related investigation could be designed for any other school by customizing the ArcGIS data layers to fit the local area. The background data sets used for this investigation include land cover data, percent tree canopy data, and personal and property crime statistics from U.S. Census data.

For best results, we recommend reviewing the teacher's guide (see "On the web"; user ID: eliteacher and password: 87dja92) before beginning the activity, as it contains additional detailed information not covered in this article. In addition, we recommend viewing the video tutorials on the website to become familiar with the ArcGIS online and the Collector app interfaces.

Day 1: Data collection

Students begin the activity by downloading a local map on their tablets that will be used for outside data collection (Figure 1). While the map is downloading, we explicitly demonstrate how to use the dichotomous key we created, using examples of different types of leaves that students will encounter during their data collection (Figure 2). Students identify the main characteristics (such as leaf shape, organization, and vein arrangement) by reading through a series of questions accompanied by displayed sample images to identify the tree species and learn whether their tree is a native or exotic species.

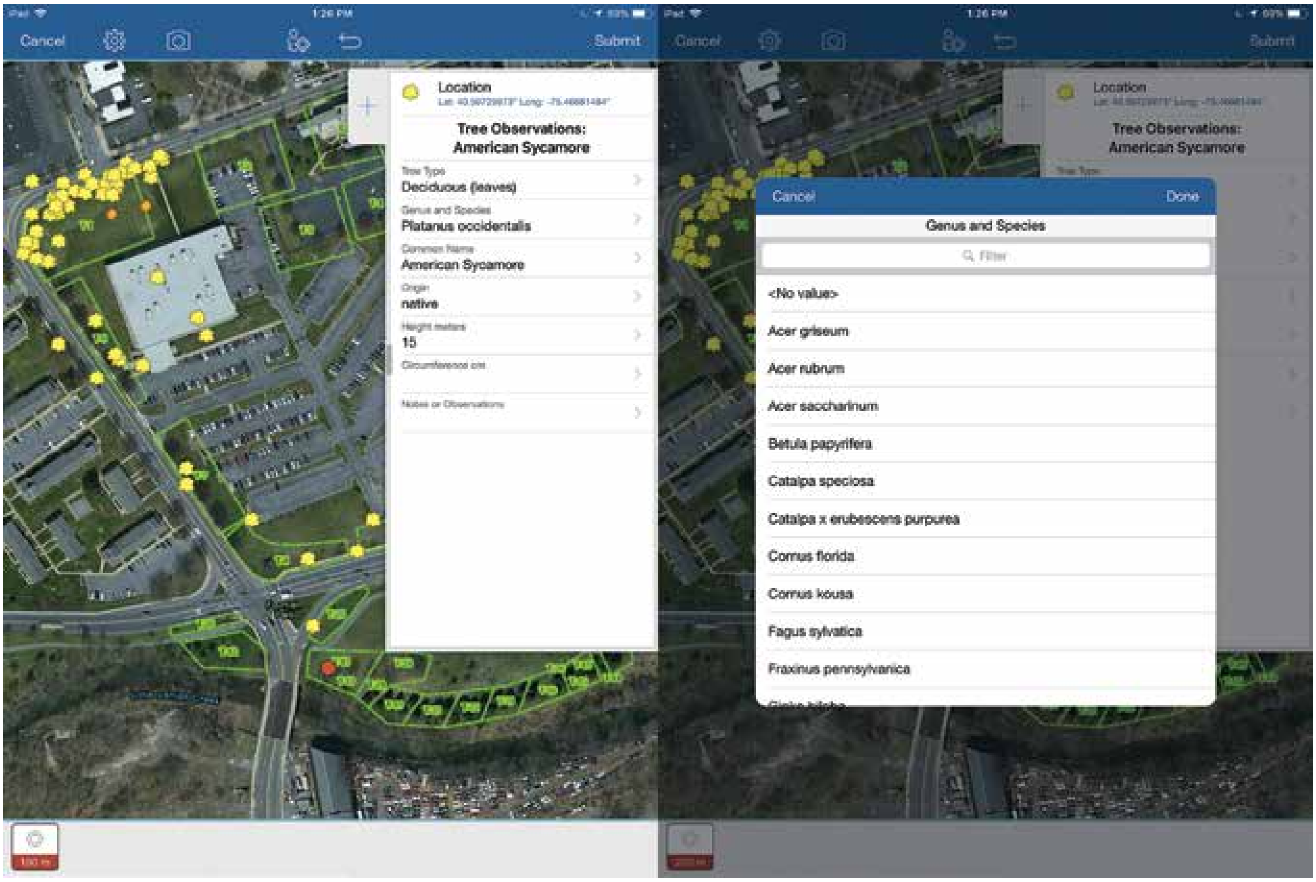
We then divided the students into small groups (3–6 students) and assigned specific investigation areas (see numbered polygons in Figure 1). We had previously recruited community members who use geospatial technologies in their careers to serve as mentors and to work with students as they collected data. Their occupations included arborists with the local power company, city planning and GIS staff, and academics and retirees with past work experience in these areas. We provided them online and in-person orientation before working with students.

Matching student groups with mentors provides students

FIGURE 1

Esri Collector app user interface showing data entry fields.

Selecting the Genus and Species option opens a customized list shown on the right. Other fields are manually filled by each student.



with opportunities to discuss careers that use geospatial technologies, and also enables the classroom teacher to circulate among groups without having to directly supervise each group. If mentors are not available for your classroom, we recommend selecting data collection areas that are in close proximity to provide appropriate safety and supervision by the classroom teacher.

Each group collects observational data about the trees within its assigned investigation area. Using the dichotomous key to identify the tree genus and species, students learn the tree's common name and determine whether it is native or exotic. At our school, located in the mid-Atlantic region, the most common genera around the building include *Acer*, *Malus*, *Picea*, *Platanus*, *Prunus*, *Quercus*, and *Tilia*. A fabric tape measure is used to measure tree circumference, a statistic related to tree height and carbon fixation. Students also estimate tree height and input evidence of animal habitats into a data field (Figure 1). Students take pictures of each tree, which are georeferenced to their data points, and evidence of bird nests or burrows in and around trees.

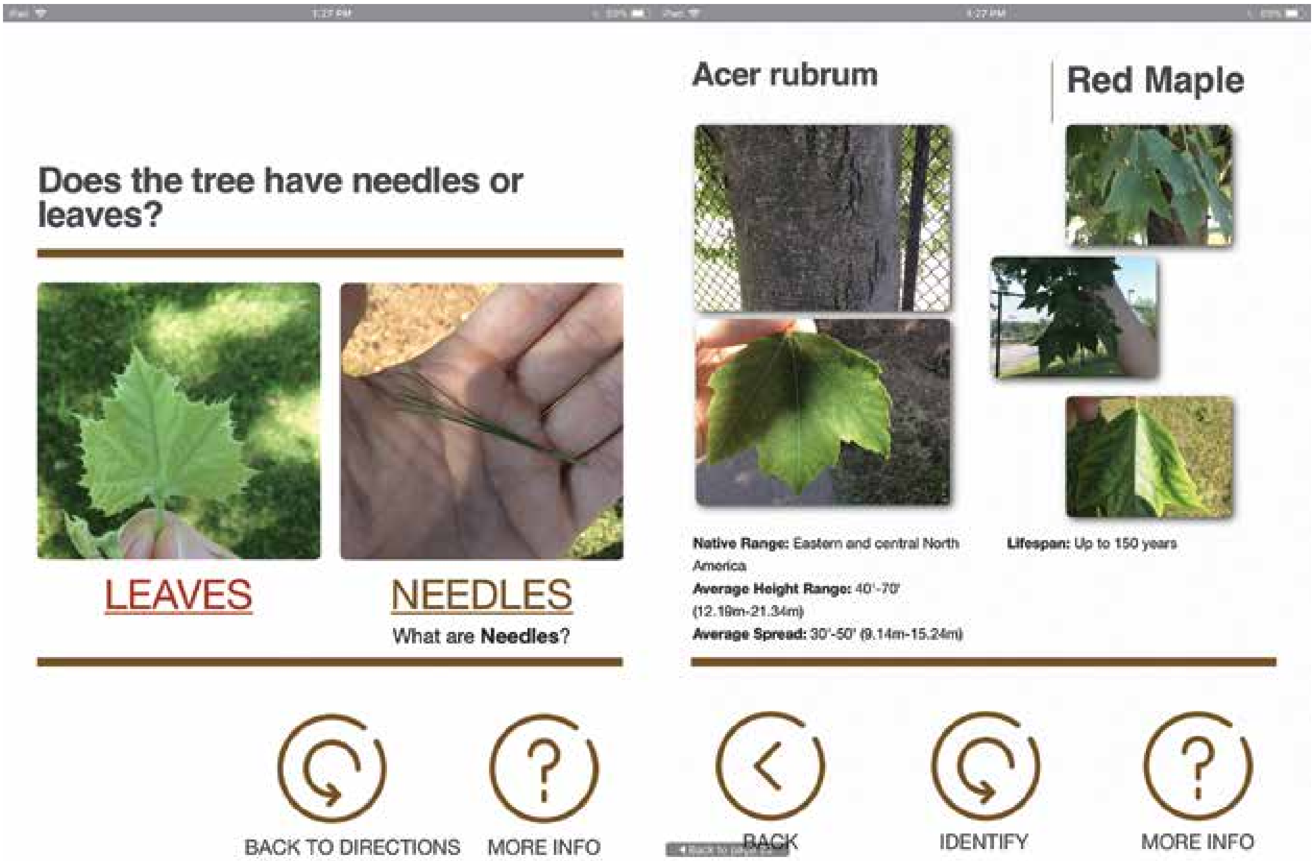
Back in the classroom, students synchronize their observations to a cloud-based service that will then display the entire classroom dataset in ArcGIS online. Students then respond to the following prompts:

- List each genus and species of tree you observed.
- Did you see any evidence of animal habitats in the trees you observed (bird's nest, rodent hole, squirrels)?
- What was the genus and species of the tallest tree you observed? How tall was it in meters?
- What was the genus and species of the widest tree you observed? What was the circumference of that tree in centimeters?

FIGURE 2

Custom tree dichotomous key for students to identify tree species during outside data collection.

Students answer simple questions such as the one shown on the left and eventually reach a tree species page like the example on the right. This provides visual prompts for the students and mentors to quickly identify trees while outside.



Day 2: Exploring patterns

The next phase of the investigation takes place in the classroom, where students can work independently or in their groups to manage, query, and analyze the cumulative class data with ArcGIS Online (Figure 3). We find it effective to explicitly model how to use the ArcGIS Online tool features to our students before they begin this part of the investigation. They should understand how to view and interpret the legend, view data from each point and in the table, and use the filter tool.

The students view their collected data and compare their findings to a data layer of planted city trees provided by our city. The students identify tree-planting patterns and think about benefits of planting shorter trees in certain locations (e.g., under power lines). Students are instructed to answer the following prompts:

- What is the most common tree on the school property? Provide the genus and species name. Is this tree native or exotic?
- Look at all classes' observations. Notice how tree species differ around the entire observation area. Where do changes in the species of trees occur? Describe any patterns you see. Be specific. Hint: Look at the color patterns on the map.
- Why do you think the tree species are different in the different locations around the school?
- Why would you want shorter trees planted in certain locations?

FIGURE 3

ArcGIS Online user interface showing student investigation areas (green polygons) and student tree identification data in the colored circles.

One student observation is highlighted showing the types of observations made by students in the field.

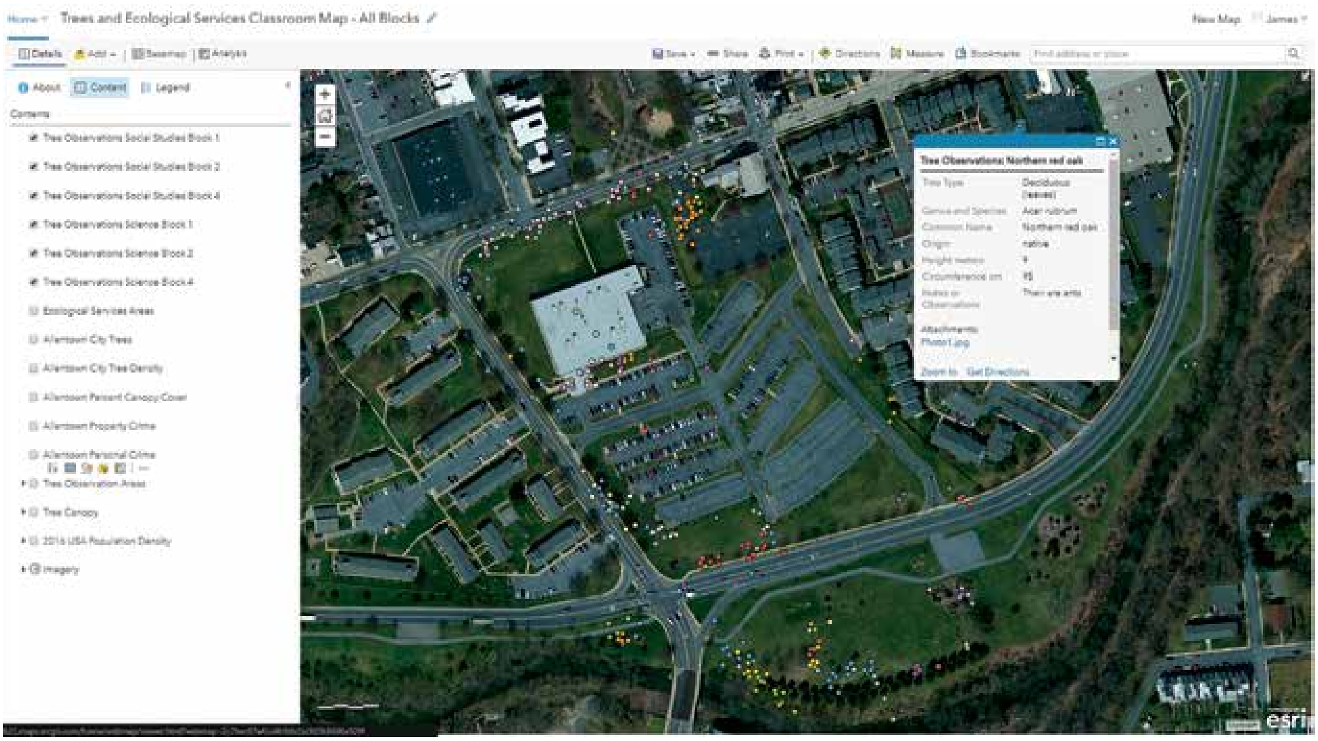


TABLE 1

Completed ecological services table for our school.

Estimated number of trees around the school:~60-100

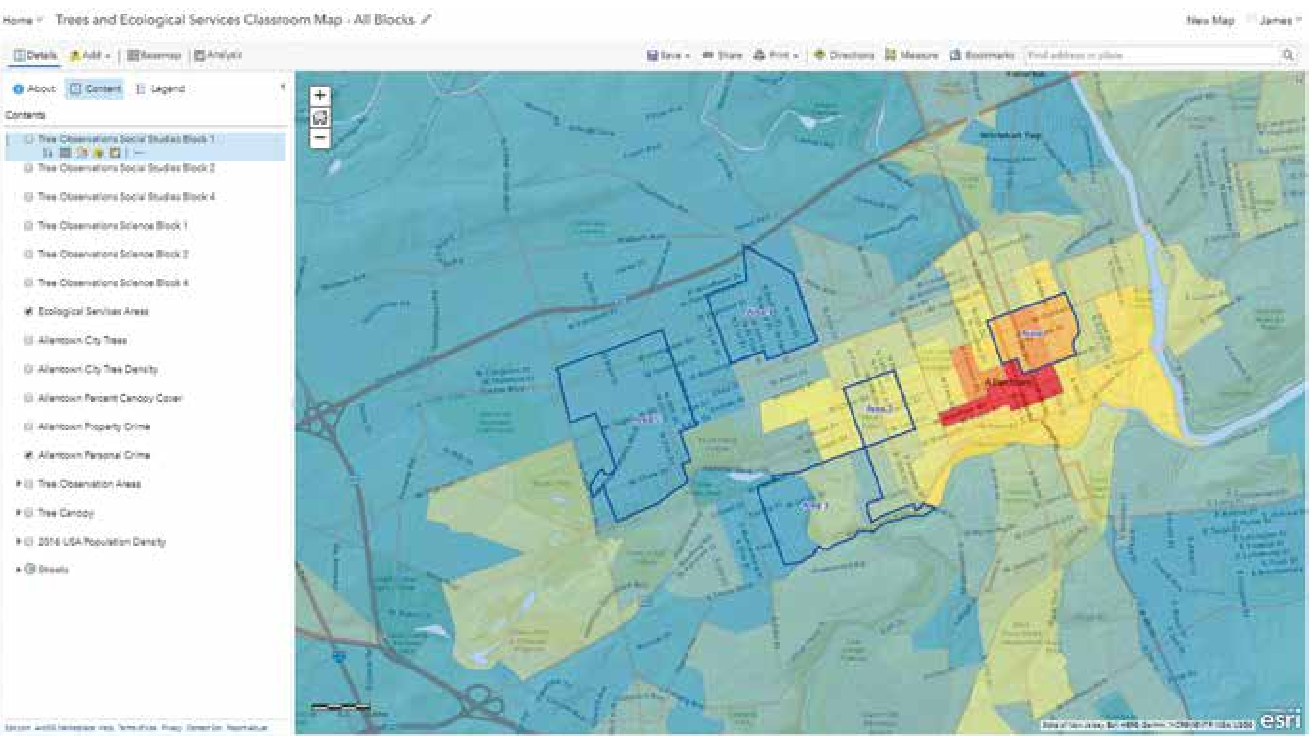
ANNUAL BENEFITS	EXAMPLE	VALUE PER TREE	TOTAL VALUE FOR TREES AROUND SCHOOL
Energy Savings	Reduced cooling costs in summer	$47.63	$2,857.80 – 4,763.00
Air pollution	Removes pollution from the air	$9.02	$541.20 – 902.00
Storm water catchment	Reduces flooding and erosion	$61.00	$3,660 – 6,100
Carbon dioxide reduction	Takes up CO_2	$1.29	$77.40 – 129.00
Aesthetic/ other	Increases property value	$89.88	$5,392.80 – 8,988.00
	Total Value	$208.82	$12,529.20 – 20,882

Total value of all trees around the school: $12,529.20–$20,882

FIGURE 4

ArcGIS Online user interface showing crime data colored from blue (lower than national average) to red (higher than national average).

Each colored region is a census block and the five white regions are the assigned student areas, each containing three census blocks.



At our school, tree species and genera change at street intersections (see color patterns in Figure 3). Student responses note that different species are planted because of a specific characteristic they have (size, aesthetic, shade), while others may have been planted for financial reasons.

Next, students are instructed to complete a data chart that displays the ecological services of a tree and corresponding value of those services. Students estimate the value of all the trees within one block of their school. A completed table with typical student responses for the school is in Table 1.

Day 3: Relationship between crime and tree cover

On Day 3, students explore the relationship between crime and tree canopy cover in their city. Students view data layers divided into census blocks throughout the city that visually display personal crime, property crime, and percentage of tree canopy cover (Figure 4). Students can also select an individual census block and view more detailed data of specific personal and property crime (Figure 5).

To assist the English learners in our school, we use design features in our instructional materials that include offset text and boldface fonts to draw attention to key terms in addition to specific visual cues to direct student use of the web GIS (Figure 5).

We assign students one of five designated regions around the city, composed of three census blocks. Each student must record the personal and property crime and percent tree canopy of their area and then calculate an average for the entire assigned area. Then, as a class, students compare different areas across the city to examine the relationship between tree canopy cover and crime (Table 2).

The data show that areas with a greater percentage of tree canopy tend to have less crime. While some students are able to detect the pattern immediately, we arrange the data table to allow the teacher to scaffold the process for identifying patterns and relationships among the data. We can draw students' attention to the first row—is the crime rate high or low? Is the tree canopy percentage high or low? Students are able to observe

FIGURE 5

Excerpt from student materials, demonstrating intentional use of text, boldface fonts to draw attention to key terms, and visual cues to direct student use of the ArcGIS online.
Map and legend display personal crime index and tree canopy data layers. Blue outlined areas display assigned student areas each containing three census blocks. Pop-up window displays data for a census block.

b. Click **Legend**. The **Allentown Personal Crime Index** layer contains statistics about major categories of personal and property crime. 100 is the national average. An example legend is shown on the right.

c. Each block on the map is a census block. Click on a block. A pop-up window displays **percent canopy cover** and **personal and property crime data** for that block (red boxes in the lower image). Scroll down to see all data and graphs.

d. Within your assigned area compare the different census blocks. What are some similarities and differences that exist between these areas?

It may be helpful to turn the **Allentown Percent Canopy Cover** layer off and on a few times so you can see how trees and crime are related.

e. Answer **questions # 10-13** below.

that in locations where crime is high, tree canopy cover is low.

Next, we draw students' attention to the last row and we repeat the questions—is the crime rate high or low? Is the tree canopy coverage high or low? In this row, we observe the inverse: where crime is low, the percent of tree canopy cover is high. If the student has not yet identified this pattern (negative correlation, or an inverse relationship between the two variables), we ask them to predict what they might see in between the extremes—given an average tree canopy percentage, would they expect a high, low, or average crime rate?

Here, we can use the middle row, which conveniently captures this in-between case. It is important to note here with students that while there is a relationship between tree canopy and crime, it is not necessarily one of cause and effect. This interesting relationship has been explored in a number of studies (e.g., Kuo and Sullivan 2001; Troy, Grove, and O'Neil-Dunne 2012; Wolf 2010).

We find this strategy helpful for the English learners in the

TABLE 2

Completed class data table for five areas of our city.
Values calculated by averaging data from three census blocks.

AREA	PROPERTY CRIME INDEX (USA AVERAGE = 100)	PERSONAL CRIME INDEX (USA AVERAGE = 100)	PERCENT TREE CANOPY COVER (CITY AVERAGE = 30%)
1	218.7	325.7	17.05%
2	139	196.3	15.35%
3	73.7	69.3	31.69%
4	45.7	23.7	26.89%
5	25.3	22.3	52.94%

classroom. As students work with these data relationships—correlation versus causation, negative versus positive correlation—the arrangement of the data table and the teacher's explicit modeling of the GIS steps involved act as linguistic supports that facilitate their comprehension. For example, the teacher can toggle between the tree canopy layer and the crime layer in the map (see Figure 5) to provide a visual cue to the inverse relationship: In one layer, the white-shaded areas (indicating low tree canopy cover) match the other layer's red-shaded areas (indicating higher rates of crime).

Correlation does not necessarily mean causation, and it may be useful to have the students consider whether trees cause a decrease in crime (or conversely, lack of trees promotes more crime), or whether high crime areas are those with densest human population or lowest income statistics. This can lead to a fruitful discussion.

Day 4: Investigating your own neighborhood

In the last part of the investigation (Day 4), students compare the tree canopy in their own neighborhood to the city average (30% tree canopy coverage in our city) and distribution, and estimate the number of trees within a block of their home using satellite imagery in ArcGIS Online or another technology such as Google Earth. Students may also take pictures to document their neighborhood and annotate their web GIS map to suggest changes that could enhance the environmental and/or societal health in their community.

Our students have provided a variety of suggestions, including the aesthetic value of trees, the importance of increasing tree canopy to reduce personal and/or property crime, enhancing species diversity in their neighborhood, and reducing carbon dioxide in the atmosphere. These answers reinforce changes that students can make in their local surroundings and to critically reflect on

how trees may benefit their community in important ways.

The teacher's guide (see "On the web") provides detailed assessment information for each question to which the students respond. We use this as a formative assessment. For a summative assessment, our students complete a map-based tree planting project in which they develop a proposal to plant trees in at least two different areas on the property of their school using at least two different species. This authentic learning task includes a detailed rubric available on the website. In addition, our students present their tree-planting proposals to mentors and members of our community and city government.

Conclusions

Overall, our students submitted satisfactory work, with a wide range of responses to questions and ideas to promote the planting of more trees in geospatially referenced neighborhoods throughout the city. Students quickly learned how to use both the Collector app and ArcGIS Online interface to collect and analyze data. Students thought critically about the benefits trees provide to their city and understood that different species have their own pros and cons that urban planners and property owners must consider.

Many students applied spatial thinking and reasoning skills while collecting and analyzing the data. Most students were able to recognize patterns in urban tree planting. For example, different species of trees along different roads represent an artificial pattern provided by city planners and property owners. Students were able to discuss some positive benefits of trees in urban environments such as cleaner air, lower cooling costs, and enhanced aesthetics.

Students had some difficulty understanding the relationship between tree canopy cover and crime statistics. Students could visualize the inverse spatial relationship between tree canopy cover and crime within the city, but inferring the potential causal relationships between trees and crime was quite difficult for some. During our analysis, we emphasized that correlation is not necessarily causation. Discussing the extent to which trees provide a local environment less conducive to crime, or to which city planners neglect urban forestry in economically disadvantaged areas proved to be more complex than could be accomplished within the context of the investigation.

We found that most of our students were actively engaged in this investigation. The students enjoyed using both the Collector app and ArcGIS Online. By the end of the investigation, our students had a more comprehensive understanding about the ecological services that are provided by urban trees. The concepts and learning activities can be adapted to for any other school environment. When analyzing their own local environment, students learn the benefits trees provide to their community and can formulate actions that can be taken to improve that community. ■

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ON THE WEB

Teacher's guide, student guide, instructional and supporting materials: *https://eli.lehigh.edu/sesi/instructional-sequence/trees-and-ecological-services*

Scavenger hunt activity: *https://eli.lehigh.edu/sesi/instructional-sequence/ecology-scavenger-hunt*

ArcGIS Online: *www.arcgis.com/home/index.html*

ESRI Collector: *www.esri.com/en-us/arcgis/products/collector-for-arcgis/overview*

Leafsnap app: *http://leafsnap.com*

VTree app: *https://itunes.apple.com/us/app/vtree/id576191197?mt=8*

PlantNet app: *https://play.google.com/store/apps/details?id=org.plantnet&hl=en_US*

TreeBook app: *https://itunes.apple.com/us/app/treebook/id340811192?mt=8*

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