Environmental Problem Solving Using GIS

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Abstract

CITYgreen by American Forest, an extension to ArcView, is being used by almost four hundred K-12 schools and universities around the country to assist in teaching science, geography, math, communications, and conservation. The software statistically analyzes the ecosystem services of trees and vegetation to calculate the dollar benefits based on site conditions. This paper describes the lesson plans created to work with the CITYgreen/GIS software in the classroom. Educators in Texas, Rhode Island, North Carolina, Washington, D.C., Kentucky, and Maryland are using the software to create an ecological analysis of their school campus and local community neighborhoods. Details are provided on how students can conduct a tree inventory that can be used for GIS mapping and analysis. This information can be used by a community to assess the current status of the tree population and identify specific actions which may need to be considered.

Introduction

Teachers across the United States are bringing Geographic Information Systems (GIS) into their classrooms to integrate geography with science, math, and communications (Audit and Ludwig, 2000). GIS is recognized as a powerful tool which works with spatial data to explore relationships that exist between geographic entities. GIS in the classroom helps foster critical thinking, problem solving, and 21st century workforce skills (Malone et. al., 2002). In addition GIS encourages community participation among young people and educators leading to more engaged citizens.

American Forests has developed a GIS software called CITYgreen that is an extension of ESRI's ArcView 3.x. CITYgreen analyzes the impacts that trees and other landcovers have on air and water. Scientific and engineering models are incorporated to predict changes to the ecosystem that forecast the ecologic and economic benefits of trees within a specified area of interest. Teachers like CITYgreen because it is a real-world application that allows students to use GIS to analyze data that the students create. Students also like the software program because it incorporates both GIS work in the classroom and outside field data collection.

American Forests, working with Lyn Malone, co-author of *Mapping Our World: GIS Lessons for Educators,* has created and classroom tested a set of lesson plans[1] that help teachers and students get started with GIS and use CITYgreen in their schools. The first lesson is an introduction that allows the students to explore the basic concepts and procedures of GIS through a computer activity to map and investigate spatial data. In the second lesson students use CITYgreen to create data layers of tree canopy and other landcover features by digitizing

[1] CITYgreen/GIS lesson plans are downloadable from American Forests website at http://www.americanforests.org/productsandpubs/citygreen/school.php.

them from an aerial image within a specified area of interest. The third lesson allows the students to build broad-based problem-solving skills by creating and analyzing alternate scenarios.

The objective of the lesson plans is for students to learn GIS and gain a better understanding of the urban ecosystem. Following the completion of the lesson plans the students will be able to explain the basic components and concepts of GIS. They will be able to create maps, analyze the spatial patterns of trees, and identify the environmental benefits they provide. The students will be able to identify factors in the urban environment that degrade and challenge the urban ecosystem. They will be able to predict the environmental impacts of changes to urban landcover.

Methodology

Teacher Training Workshops

American Forests offers hands-on training workshops for teachers; a minimum participation of ten schools per workshop is optimal in terms of class size and cost effectiveness. The workshops have been held at a local school's computer lab or at American Forests' headquarters in Washington DC.

Teachers receive step-by-step instructions led by two trained instructors who are also classroom teachers. The workshops are typically 1-1/2 days long. At the end of the workshop, every teacher receives all of the necessary materials including digital data of their school, CITYgreen and ArcView software, and the training guide to use this with their students. Follow up support is provided by phone and email.

Student Involvement

Students begin the program with hands-on computer learning using GIS to create data. The students use a projected aerial photo as a basemap, preferably 1 meter resolution or less to digitize the landcover features (see Figure 1). Two polygon shapefiles are created digitizing the landcover features, one that has the tree canopy features and the other containing all other landcover features. Each tree canopy polygon is assigned a unique number by the CITYgreen software. A field map is created detailing the spatial distribution of trees labeled with the unique number assigned to each tree (see Figure 2). The students use CITYgreen to create an inventory sheet that allows them to write down attributes about trees, such as species, height, diameter, and health rating throughout their field survey.

Figure 1: Aerial photo of McKinley High School, Washington DC

Source: DC Planning Office

During the field exercise students apply specific math skills by using a variety of tools and formulas to evaluate each tree. The software requires a measurement of the height of each tree. Students can incorporate the geometry concept of the isosceles right triangle to find the height of a tree. They derive the height by standing at a 45 degree angle from their location to the top of the tree. Using a measuring tape, students measure from their location to the base of the tree. Based on the isosceles right triangle, the distance will be equal to the height of the tree.

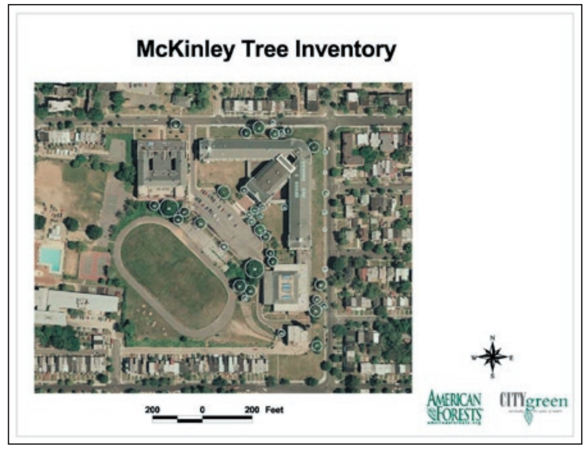

Figure 2: Map of McKinley High School with trees digitized and labled.

The diameter at breast-height must also be determined. Students use a diameter-at-breast height (DBH) tape to find the circumference of the tree 4.5 feet above the base of the tree. If a DBH tape is not available the students can use a regular tape to find the circumference. Diameter can be determined by dividing circumference by Pi (3.14).

Species of the tree can be determined by using dichotomous tree guides that allow the students to investigate its unique characteristics. With a little practice, students quickly learn to identify species without needing the guides.

The students also look at the condition in which the tree is growing. For example, is it surrounded by impervious landcover or is it in an open area that allows for maximum infiltration and root spread. A relative value of *Good, Fair, or Poor* is assigned as growing conditions. The tree must be evaluated to determine its overall health. Students can follow an evaluation sheet that is included with the reference materials to rank the tree's health as *Dead, Poor, Fair, Good, or Excellent*. This requires the students to look for exposed roots, damaged or missing bark, leaf discoloration and other visible defects.

After the inventory is complete, students return to the classroom and enter the collected information. They use their field data collection form generated in the CITYgreen software, and manually enter the information into the canopy layer datatable (see Figure 3). The result is a geographic database of the tree canopy with attributes that allow for more detailed mapping and analysis.

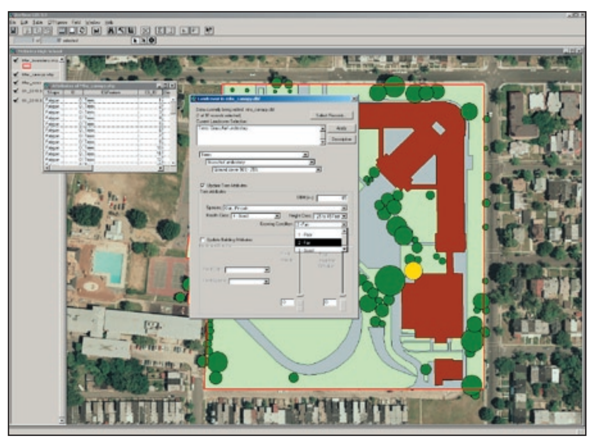

Figure 3: Updating tree attribute information into database using CITYgreen.

The CITYgreen software allows students to conduct an environmental analysis of their trees to investigate benefits these trees provide for cleaning the air, storing carbon, reducing home cooling costs, and reducing stormwater runoff. Students are also able to create and analyze alternate landcover scenarios to better understand the relationship of changing landcover types on environmental impacts. For example, a student will see that if tree canopy is decreased 10% and impervious surfaces increase by 10%, that it will have a negative affect on the environment, leading to more stormwater runoff and possibly to additional flooding.

Models in CITYgreen

CITYgreen incorporates ecological models developed and peer-reviewed by scientists and engineers to calculate the environmental and economic value of trees. The output report details the landcover site characteristics of a specified area of interest. The UFORE model (Nowak and Crane, 2000) developed by the US Forest Service is used to derive the air pollutant removal capacity of the trees as documented in fifty-five cities across the U.S. The dollar value associated with each pollutant is based on avoided externalities, or costs to society, such as public health-related illness as a result of air pollution. Values are set by states' Public Service Commission.

The carbon model was also developed by researchers at the US Forest Service. The analysis reports the amount of carbon stored and sequestered within the biomass of the trees (Nowak and Roundtree, 1991; McPherson et. al., 1994).

The stormwater model used in the analysis was developed by engineers from the Natural Resource Conservation Service (NRCS) to determine the volume of runoff generated if the trees are removed (Technical Release 55, 1986; Woodward et. al. 1987). The cost associated with the runoff is determined by the costs to construct a retention/detention facility for the excess runoff if the trees are removed. That cost is measured in dollars per cubic foot of runoff.

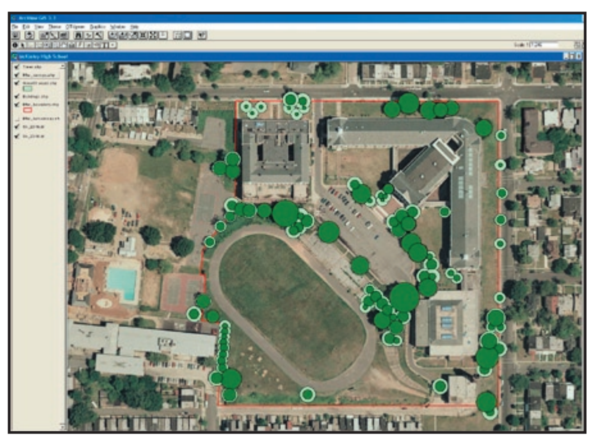

Figure 4: Dark green circles are current trees, light green are trees modeled after 30 years of growth.

CITYgreen's energy conservation analysis estimates the benefits of trees' direct shading of one and two story residential buildings (McPhearson et. al., 1993). CITYgreen determines how many kilowatt hours of electricity are saved from trees surrounding a home. A dollar value is assigned based on the amount of kilowatt hours the trees saved and local energy costs associated with cooling.

The CITYgreen program has a growth model that allows the user to grow existing tree canopy up to 50 years. Upon reviewing figure 4 the existing tree canopy is represented by the smaller circles and the 30 year growth is represented by circles surrounding them. Notice that some trees have grown more that others while some have not grown at all. The trees with a lot of growth are young, have good growing conditions, and are a species that will mature into a large canopy. The trees that have little or no growth are probably at current maximum growth capacity or in poor health with poor growing conditions. The canopy growth factor is dependent on the current state of the tree.

This model is especially beneficial when students incorporate a tree planting with their inventory and analysis. Students can grow the young tree they plant to see how that tree will look in 10, 20, or 30 years. They can then run an analysis to see how that tree will help the environment in regards to removing air pollutants, storing carbon, and mitigating stormwater.

Success Stories

CITYgreen has been an excellent introduction to GIS and offers experiential learning in environmental science, social studies, math, and geography. Lyn Malone who had taught in public schools for 32 years as a social studies teacher recognized the advantages of using GIS in the classroom. In 2000, she and a colleague launched Project One, Two, Tree in response to a Rhode Island initiative that required every town to include an urban forestry component in its comprehensive plan. Malone thought it would be a great community service for the students to create a tree database that the town could expand. They piloted the project in their town of Barrington, where 80 students learned about urban forestry and used CITYgreen to create an inventory of their middle school's 217 trees. They also analyzed the range of species and documented their condition. During the next year, Malone trained middle and high school teachers from ten towns to conduct similar teaching experiences.

McKinley Technology High School in Washington DC, is a newly reopened inner city school focused on providing technology skills applicable to an array of careers. Drew Swierczek, a first year teacher, developed "Community as Laboratory", an elective that uses CITYgreen software to teach students GIS and the environmental benefits of urban trees.

Swierczek had never heard of GIS prior to joining McKinley. Subsequently, he used the CITYgreen manual and lesson plans to teach himself the basics of GIS. He then incorporated the CITYgreen lesson plans and created an atmosphere where both he and the students learned from one another. The freshmen and sophomores conducted a tree inventory of their schoolyard and ran alternative scenarios for various planting schemes. Next year, Swierczek plans to expand beyond the schoolyard to adjoining neighborhoods to inventory trees. He also envisions teaching a social studies course using GIS applications to analyze how a city park divides the city economically.

In 2004, H-E-B, a food distributor based in San Antonio, TX, celebrated its 100 year anniversary. As part of the celebration they were performing many community service projects throughout the state of Texas. American Forests teamed with H-E-B in a project called "Trees for Texas" that invited sixth through eighth grade public school educators within H-E-B's service areas to apply to participate in a special environmental education project. A total of 40 schools were selected to receive ESRI Geographic Information Systems (GIS) and American Forests' CITYgreen software and attend a training workshop held by American Forests. The trainings were successful and the teachers were given the tools, resources, and knowledge to implement CITYgreen and GIS into their classroom. In addition, each school received five trees from American Forests Historic Tree Nursery for planting on their school campus.

Conclusion

The success stories mentioned are just a few in a list that is growing rapidly around the country. In the two years that CITYgreen education program has been marketed to middle and high schools, students, teachers, and school administrators have given the program a very positive reaction. These lesson plans help teachers and administrators bring technology into the classroom. Not only does this program educate students in core academic subjects, but it provides real world issues around conservation and urban planning. American Forests is encouraged by the success so far. The organization's mission of growing a healthier world with trees is being passed on to the next generation.

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