Title: Analyzing the "Green Data Layer" in the Classroom

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ABSTRACT

Analysts at American Forests have been using satellite imagery and GIS to create a "Green Data Layer," documenting the spatial location of urban forest canopies for over ten years. This layer is used to determine the environmental and economic benefits that trees provide to cities. Educators across the country are learning how to implement this technology in their classrooms. Teachers will discover how to build engaging, real-world projects to teach geography; enhance the students' computer skills; improve math and science knowledge; and develop an understanding of how ecosystems function. The use of raster landcover data will be demonstrated. Find out how your school can start using the "Green Data Layer" to engage students in real world problem solving.

Geographic Information Systems (GIS) permeates our everyday lives as an integral part of international, national, regional, state and local planning from emergency services to utilities, transportation to communications to global positioning systems (GPS). GIS is used in many ways, such as to coordinate census data, route buses, redistrict schools, and analyze crime and health statistics. The visual display of the locations and descriptions of the data has proven valuable when solving multi-faceted real-world problems such as those found in the environment.

The power of GIS lies behind its design for collecting, storing, manipulating, and displaying data referenced by a spatial or geographic component. Information is stored in layers that are linked to a map by geography. The user can change these maps or visual representations of reality almost instantaneously. The layers may contain widely varying kinds of information that can be queried, combined, analyzed, and displayed to create new representations.

GIS is truly a real-world technology with multiple applications in environmental science to which students can contribute, becoming a part of the sustainable communities of the future. Students can visualize data, organize, store and analyze data from past years, easily manipulate data, and expand the scale of exploration, allowing them to search for and create multiple patterns and explanations. Thus, GIS can facilitate the combination and construction of numerous questions and answers through active inquiry as they investigate their environment. In fact, this technology can allow students to visualize environmental models that would have otherwise been too complicated for them to understand (Stubbs, Hagevik, & Hessler, 2003). Students also become more spatially aware and concerned about data quality (Sanders, Kajs, & Crawford, 2001). When students learn with GIS, they not only learn subject matter, they learn how to apply problem solving approaches (Bednarz, 2000).

GIS is a spatial technology, requiring visual-spatial skills that are keys to success in today's increasingly high-tech society (Kotulak, 2000). Spatial thinking is the ability to manipulate three-dimensional objects in space and to see new relationships (Baker & Piburn, 1997). Spatial thinking can be defined as the ability to see your world in your mind, to manipulate it and to explore it. Since interaction with the environment takes place in a three-dimensional space, the development of viable schemata of the world is linked to our spatial ability. Bybee & Sund (1990) state that spatial skills are essential to the development of high mental functions. This "new" way of thinking and learning from a spatial-visual approach is seldom addressed in instruction. Although textbooks are highly verbal, science relies heavily on visual images. Complex scientific relationships and principles can be more effectively communicated and understood through the use of visual images rather than with text alone. Pallrand and Seeber (1984) reported that spatial ability enhanced student's ability to make sense of data. Spatial ability has been linked to logical and scientific reasoning and mathematics competencies (Clements, Battista, Sarama, & Swaminathan, 1997). Could using GIS in schools emerge as a method of developing the spatial abilities of students?

CITYgreen (American Forests, 2000b), a GIS extension, is being used by more than two hundred cities as a powerful GIS application for land-use planning and policy-making. The software statistically analyzes the ecosystem services of trees and vegetation to calculate the dollar benefits based on site conditions. Engineers and planners can then model development scenarios, evaluate landscape ordinances, and calculate storm water management costs. Foresters use the program to plan maintenance, planting, and preservation of trees. Educators use CITYgreen to teach forestry, environmental studies, planning, and landscape architecture.

Middle and high school teachers and students in Rhode Island, North Carolina, Texas, Washington DC, and Maryland have used Citygreen, GIS, and remote sensing images of their schools to create an ecological analysis of their schools based on trees and tree canopy cover (Harte, 2002). For example in Rhode Island, the *One, Two, Tree* inventory is an interdisciplinary project that merges geography, natural science, and environmental studies with GIS to address a significant community issue—the protection and preservation of community forests. This project has expanded to include 500 students and 10 communities (English & Feaster, 2003).

Citygreen involves students in collecting data on trees, buildings, impervious surfaces, grasslands, bare ground, air conditioners, and shrubs on their school campuses. GIS formulates statistics on the site and reports carbon sequestration and storage, pollution removal benefits, energy conservation, and tree growth models. If you wish to run a CITYgreen analysis over a large area (e.g. entire cities, counties, watersheds, regions, etc), it is best to work with raster data. Before running a large area analysis, using raster data with CITYgreen, you will need to have installed the Spatial Analyst™ extension for ArcView 3.2

Raw raster satellite data contain widely fluctuating reflectance values for each pixel in the image. Water, trees, buildings, and concrete all have different albedo values, and trained image analysts spend considerable time identifying the landcover associated with each of these reflectance values. Once they determine and verify landcovers (called ground-truthing), the analyst can then apply the values over the entire study area. The result is a fully classified scene with pixels accurately assigned to buildings, streets, grass, water, and trees. The main section of the CITYgreen Analysis Report is dedicated to the ecological and economic benefits provided by the trees in the Areas of Interest.

For example, CITYgreen estimates the annual pollutant removal capacity of trees within an Area of Interest using removal rates for urban and suburban trees established by the USDA Forest Service. Dollar benefit estimates produced by CITYgreen are based on indirect or "externality" costs associated with a pollutant once it enters the atmosphere, at rates established by the local states' Public Utilities Commissions. Pollution removal is reported in pounds, on an annual basis. Results include:

- Ozone (0_2) removal and related dollar value
- Sulfur dioxide (SO_2) removal and related dollar value
- Nitrogen dioxide ($N0_2$) removal and related dollar value
- Removal of particulate matter 10 microns or less(PM10) and related dollar value
- Carbon monoxide (CO) removal and related dollar value
- The sum of individual dollar value calculations for each pollutant

CITYgreen estimates the total carbon storage capacity and the annual carbon sequestration rate of trees within Areas of Interest, using formulas adapted from USDA Forest Service research. CITYgreen references data from the canopy theme to make its estimates. For individual trees, CITYgreen considers trunk diameter information recorded in the canopy layer theme table. For forest patches and raster datasets, CITYgreen uses overall canopy cover to calculate carbon sequestration values. If you have not specified a diameter class for individual trees , CITYgreen cannot calculate carbon sequestration rates. Carbon results include:

- Age distribution of trees in the Area of Interest.
- Carbon stored by trees in the Area of Interest (reported in tons).
- Sequestration rate of trees in the Area of Interest (reported in tons per year).

The program estimates annual sequestration, or the rate at which carbon is removed, and the current storage in existing trees. Both are reported in tons.

Using curve numbers for urban and suburban soils developed by the USDA Natural Resources Conservation Service, CITYgreen estimates the stormwater runoff reduction capacity of trees within an Area of Interest. The software employs methods documented in *Technical Release 55: Urban Hydrology for Small Watersheds*, commonly known as “TR-55” to estimate the flow of water over land within the sample/study area boundary.

CITYgreen calculates the impact of tree canopy and vegetation on stormwater runoff volume for an Area of Interest. The dollar benefit is calculated by multiplying the volume of stormwater reduced by trees by a local cost per cubic foot for mitigation (e.g. the cost for building retention ponds, building additional stormwater management facilities, or treating water). Stormwater results include:

- Average 2-year, 24-hour rainfall.*
- Soil hydrologic group.*
- TR-55 Curve Number under current conditions and without trees.
- Runoff volume under current conditions and without trees (reported in inches).
- Value of stormwater control performed by existing trees (reported in dollars).

Using CITYgreen, informed decisions can then be made regarding the management of the outside environment. Teachers who have used CITYgreen GIS in their classrooms have said:

- “It is as important for us to manage our green environment as our building environment. We are planning a nature trail through our school campus. We have received grant money to plant trees removed due to building renovations.” (Ginny Owens, Ligon GT Middle School, Raleigh, NC)
- “We can do tree-loss counts resulting from the construction on our campus.” (Sarah Hannawald, Greensboro Day School, Greensboro, NC)
- “My students have learned how to collect data, make observations, formulate hypothesis, solve problems, and ask questions.” (Pat Schweigert, Leesville Middle School, Raleigh, NC)

- “My students have studied the impact of human development and the consequences of population density.” (Val Vickers, Greensboro Day School, Greensboro, NC)
- “Using GIS has showed me how to take science outside and relate it to the local environment. It has shown me how to integrate technology into the science curriculum in a new and better way.” (Carolyn Moser, Leesville Middle School, Raleigh, NC).

Examples of problem questions solved by students using CITYgreen on their school campuses include:

PROBLEM QUESTION	CONCLUSION
What would happen if all the Bradford Pear trees at Carrington were replaced with Red Oak and Southern Magnolia trees?	The dominant tree on campus would become a red oak tree, which would improve wildlife benefits but carbon benefits, pollution removal benefits, and energy benefits would remain the same.
What would happen if the impervious surfaces increased by 70% and the trees decreased by 10%?	The carbon storage, pollution removal benefits and stormwater benefits decreased. If you want to make changes to the environment, you should consider the environment first.
How would the trees, carbon benefits, pollution removal benefits, stormwater runoff, and energy savings change if the study area were redrawn to include only the digitized area around the school?	The bare area decreased because we eliminated the bus lot. Stormwater benefits increased as a result. More trees should be planted around the school.
What would happen if 100%, 50%, and 25% of our trees died?	The air would not be as clean with fewer trees. We need to plant the trees we cut down due to building expansion.
What would happen if impervious surfaces increased by 75% and water by 50%?	The stormwater benefits and pollution benefits decreased. We suggest that impervious surfaces be limited at Carrington.
What would Carrington be like without trailers and instead there were trees?	More trees would save Carrington over $500 per year in carbon and air pollution benefits. A few trees make a big difference.
What would happen if 50% of the trees were cut down or destroyed?	Carbon storage was lower and runoff increased. This would contribute to global warming. There would be less food for wildlife.
What would happen if water increased by 2% and trees decreased by 50%	If water increases then there are fewer trees. There is a decrease in the tree savings and overall energy benefits. The number of species of trees also decreased.

Students are using increasingly sophisticated techniques to explore their local environment and their role in shaping its future (Harte, 2002). We are at the beginning of an explosion and expansion of the use of environmental data to help us solve the problems of humankind. It is important that all students learn how to use technology in their everyday lives and to be technologically prepared for the jobs of the future. CITYgreen and GIS methodology integrates science, mathematics, and the newest technologies (GPS, remote sensing and wireless hand-held devices) that will aide in preparing educators and students for the challenges of the future (Stubbs, 2003).

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