Remote Sensing Delivers Value to Local Governments

A growing number of local governments are discovering the value of remote sensing for fueling innovative applications and procuring grant funding.

*By Sudha Maheshwari, general manager, Sanborn (*www.sanborn.com*), Colorado Springs, Colo.*

Geographic information system (GIS) programs long have used vector data for a range of local government applications, ranging from creating and updating parcel data, roads and building footprints to modeling networks such as water, sewer and electric utilities. Less known is the role remote sensing technologies play in managing local government functions. More local governments are leveraging remotely sensed data, derivative products and technologies as effective, economical ways to solve problems and make good decisions.

As an added bonus, remote sensing often is promoted through state and federal grants, as these agencies have a longer tradition of using remotely sensed data from airborne and satellite platforms. Such funding often allows for intergovernmental partnerships that lead to a win-win strategy, as data collected at the local level also can be leveraged at state and federal levels for better decision making. In addition, some research-based initiatives have been established to promote remote sensing as an efficient, effective way to collect data.

Common Applications

To better understand how remote sensing data can be used for local government applications, consider three different datasets: impervious data, land use/land cover data and change detection data.

As GIS professionals are called on to support initiatives for a more sustainable environment, the use of imagery and raster tools will become essential for an array of tasks.

Impervious Surface Mapping

Impervious data delineate all human-created surfaces that don't allow water to penetrate through them into the ground—buildings, roads, parking lots, decks, canopies, etc. Hard rock or other naturally impervious surfaces usually aren't considered impervious for mapping purposes.

Impervious surfaces generate runoff that can create costly storm water treatment and management problems. In metropolitan areas across the United States, construction costs of retention facilities that store the excess volume of storm water generated during the last 20 years have been estimated at more than $1.4 billion.

Rapidly growing communities face the challenges and capital investment required to build and maintain retention facilities to store and treat excess volumes of storm water. Therefore, better information regarding current and projected changes is increasingly important. Under any scenario the excess runoff generated by increasing impervious surfaces is problematic, but in urban environments these impacts often are amplified and lead to

increased capital expenditures, flooding, stream bank erosion and increased water pollution. Furthermore, the combined sanitary and storm water sewer systems present in many older cities pollute and degrade streams, and many cities spend millions of dollars in structural fixes to comply with the U.S. Environmental Protection Agency's Clean Water Act.

Those interested in preventing and/or mitigating the impacts of urbanization on water resources need to know the location and extent of impervious surfaces, their relationship to the water cycle, their impacts on waterways and the ways this relationship can be used to better inform and educate the community about storm water plans and costs. In addition, many municipalities have developed storm water utility billing systems that assess a fee based on the amount of impervious surface per parcel or per customer to help build a fair pay-as-you-use approach to charging customers, optimize revenue and offset the increasing costs of storm water management.

Such fees and other best management practices also offer home owners and businesses knowledge and incentives to reduce the amount of storm water going into the system all at once. Thus, an accurate assessment of impervious surfaces often is the baseline by which many communities measure landscape impacts on water quality.

Impervious surfaces can be derived using a traditional planimetric approach or through semi-automated approaches that use remote sensing tools and techniques. The traditional planimetric approach typically involves compiling features such as roads, buildings, parking lots, driveways, sidewalks, etc., using photogrammetry or heads-up digitizing techniques in a vector environment. This approach is suitable for smaller geographies such as a city or a small county, but it tends to be cost-prohibitive for larger areas. Many cities already have captured some of these features, but typically sidewalks, driveways and parking lots aren't part of a planimetric approach.

Capturing impervious surfaces using semi-automated approaches harnesses the ability of the computer to recognize such surfaces based on their color (spectral response), texture, size, shape and pattern. Analysts train the computer to recognize different types of impervious surfaces and then direct the computer to find other areas that have similar characteristics or properties. Once the computer has identified areas automatically, an analyst manually edits any confused areas—i.e., areas that look like impervious surfaces but aren't, such as baseball diamonds or agricultural fields with high reflectance.

This approach is more cost effective and efficient than the planimetric approach, plus it lends itself better to change detection. The product derived from this approach is primarily a raster product and has a somewhat pixelated appearance, but it can be converted to a vector using smoothing algorithms.

Depending on the classification resolution, the appearance of the impervious data can be more pixelated or less. For regional applications, 2.5-meter pixel resolution is sufficient, but the pixel size for more local applications is usually less than 1 meter. In some applications where storm water utilities are the reason for acquiring the product, higher resolutions of 6 inches or better are desirable to meet accuracy requirements.

The pervious/impervious layer comprises two classes: pervious and impervious. It's not as simple to break down the impervious features into buildings, driveways, roads, etc. However, datasets such as

For regional impervious surface mapping applications, 2.5-meter resolution (top) is sufficient. More local applications may require 1-meter (middle) or 6-inch resolution (bottom) to meet accuracy requirements.

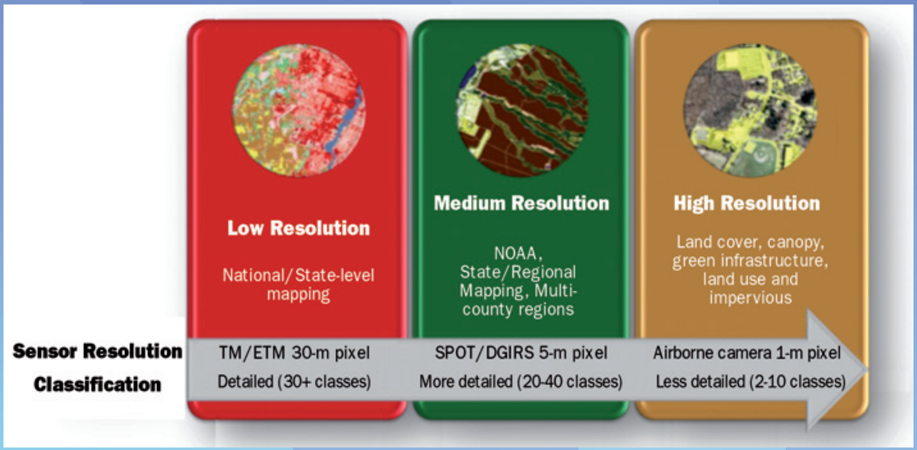
light detection and ranging (LiDAR) data, existing planimetrics and other datasets can be used to further classify impervious features into various categories at an additional cost. Budget requirements dictate the threshold at which planimetrically derived data are preferable to semi-automated methods. Generally, if further classification is essential, the best alternative may be to compile planimetrics manually or enhance the data to include any missing features such as sidewalks, etc., rather than start from scratch. This is particularly the case when there's already a significant investment in planimetric data.

The impervious data layer can be summarized by any set of GIS polygons. Typical storm water applications derive the amount of impervious features by parcel to determine the storm water fee for each parcel. The city of Ann Arbor, Mich., uses such an approach for its storm water utility fee and has acquired an original impervious layer and two updates so far. Other jurisdictions around the country are also at various stages of implementing this approach for storm water billing. For more information, visit *www.a2gov.org/government/publicservices/systems_planning/waterresources/Stormwater/Pages/StormWaterRates.aspx.*

Any local government GIS organization called on by other departments to support such essential tasks must look beyond the world of points, lines and polygons and be prepared to take the plunge into the raster world.

Land Use/Land Cover Mapping

Employing a current inventory of land use and land cover and a way to monitor change over time is essential for responsible land management. Measuring current conditions and how they change can be achieved easily through a land cover classification, which quantifies the current land cover in a series of thematic categories. Using remotely sensed imagery and semi-automated classification methods provide a cost-effective, accurate way to derive and maintain this information.



Higher resolution imagery captures more detail and smaller features, making such imagery more suitable for local uses.

Although remotely sensed data long have been used for land cover mapping, most applications have used low-resolution imagery such as Landsat multispectral or other satellite data. While useful, such data are limited for local government applications.

Now local governments often compile land cover data from high-resolution 4-band imagery. As the number of bands decrease, the number of classes that can be captured also decreases, but higher resolution allows the ability to capture more detail and smaller features, making such imagery more suitable for local uses.

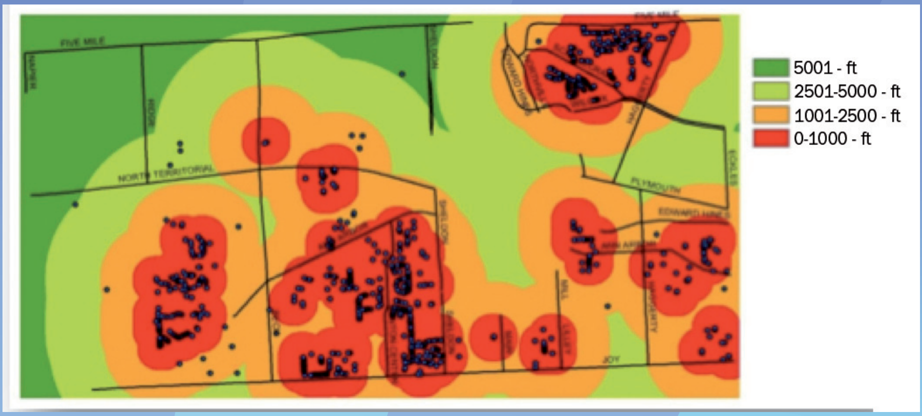
One dataset commonly used in local government is green infrastructure land cover data. This is a product that classifies high-resolution imagery into five classes: impervious, woody vegetation, nonwoody vegetation, water and barren. Additional classes are added in some cases, breaking woody into coniferous, broadleaved and mixed and nonwoody into cropland and grassland. Because the imagery used is high resolution—usually a 1-meter pixel—the smallest object captured in the map is usually about .01 acres (435 square feet). This allows one to classify small clumps of trees and lawns as well as impervious surfaces.

Green infrastructure data are a critical component for local governments that have canopy ordinances in place, such as the city of San Antonio (see *www.sanantonio.gov/dsd/pdf/R_4298_20100518110056.pdf*), or for those interested in adopting canopy goals or for finding areas where trees can be planted to meet canopy goals. Many local governments also have acquired these datasets to understand holistically the dollar values of their green infrastructure.

Ikonos 1-meter, 4-band satellite imagery

Green infrastructure data layer for American Forest CITYgreen program

Products such as American Forests' CITYgreen software use land cover classifications to generate reports that help users quantify the value of green infrastructure.



Planners in Plymouth Township, Maine, used land cover classification data to replace trees lost to emerald ash borer infestations.

Products such as CITYgreen have been widely used to integrate land cover information with models for rainfall, air pollution, soils, etc., to estimate the return on investment from green infrastructure to make a case for such investments to continue. The CITYgreen product uses land cover classification data to provide reports to quantify the value of green infrastructure.

Although CITYgreen isn't supported anymore, other decision-support tools, such as i-Tree (*www.itreetools.org*), perform similar analyses. Similarly, once these data are created, they can be used in conjunction with other data such as parcels, road right of ways, etc., to identify suitable areas for planting based on various exclusion and prioritization criteria.

For example, planners in Plymouth Township, Mich., wanted to increase canopy by planting on public lands only, in the Wayne County right of way and with the goal that plantings would be used to replace trees lost to emerald ash borer infestations. Other watershed considerations also were used to decide where to plant trees, thereby prioritizing watersheds with lower water quality. Likewise, two classification timeframes were developed for Palm Beach County, Fla., to help identify the amount of canopy lost to hurricanes.

Change Detection

Change detection is another critical remote sensing application for local governments. Image-to-image change detection can be accomplished using remote sensing tools and technologies, and local governments procure high-resolution imagery regularly. Using two timeframes, image-to-image classification can provide where changes are occurring as a "cue map." A cue map can be used to update parcels, building footprints, previously acquired land cover, roads, etc., or simply help quantify changes in land cover and land use between two timeframes.

Change detection maps resulting from image-to-image comparisons have some false positives and missed positives due to different flight lines and other issues. Moreover, such maps aren't suitable for small changes such as home extensions, new decks or other small changes. However, such maps provide an economical way to identify changes that can be leveraged to update datasets or build-out analyses, tree canopy data and other land cover datasets.

Using two timeframes, image-to-image classification allows local governments to identify where changes have occurred.

In recent years, image-to-image change detection has been enhanced by looking at changes between pixels as well as contextual changes in the surrounding pixels, change patterns, etc. A computer can be trained to add additional factors such as texture, ratio bands, etc., to detect changes much more accurately.

Preparing for the Future

The datasets discussed here are only some of the many applications with which remote sensing technologies and tools are helping local government users. Other applications, such as using remote sensing data and tools to find leaking septic systems or leaks in insulation on building roofs, hold a lot of promise.

In addition, several federal agencies have invested in remote sensing technology for local government applications. For example, the U.S. Environmental Protection Agency (EPA) has funded the creation of maps showing land development from 2004 to 2008 in Maine through the Collaborative Science and Technology Network for Sustainability research grant, and many jurisdictions get funding from EPA to create impervious and land cover data. However, there are many other sources of federal funding that local governments can leverage. Recently, the Southeast Michigan Council of Governments received a Sustainable Communities Regional Planning grant from the U.S. Department of Housing and Urban Development that included the development of high-resolution land cover data for a seven-county area in southeast Michigan (see *www.semcog.org/Sustainability.aspx*).

As GIS professionals are called on to support initiatives for a more sustainable environment, the use of imagery and raster tools will become essential for an array of tasks, including storm water modeling, predicting nonpoint source water pollution loads, assessing storm water utility fees, measuring urban development/build-out analysis, assessing and monitoring watershed health, land use planning, and designing comprehensive strategies and best management practices for reducing storm water apart from centralized structural solutions. Any local government GIS organization called on by other departments to support such essential tasks must look beyond the world of points, lines and polygons and be prepared to take the plunge into the raster world. EIJ