REMOTE SENSING AND GEOSPATIAL ANALYSIS LABORATORY
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UNIVERSITY OF MINNESOTA
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COLLEGE OF NATURAL RESOURCES
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DEPARTMENT OF FOREST RESOURCES

Impervious Surface Mapping Using Satellite Remote Sensing

Like many cities across the United States, the landscape of Eagan, Minnesota is changing. Residents are building new homes and the city is laying more roads and sidewalks. The result is a city landscape dominated by pavement, concrete and rooftops.

Research suggests that these man-made, impervious surfaces can decrease the quality of surrounding natural resources. For this reason, environmental analysts have traditionally used aerial photographs to create maps of impervious surface area, which are in turn used to study how increasing amounts of impervious surfaces are impacting the environment.

More recently, the Metropolitan Council of Minnesota has been evaluating the use of satellite imagery to generate impervious surface area maps. The work is being conducted in collaboration with the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory. This fact sheet is an overview of how this new cost-effective approach has been used to create maps of impervious surface area in the Twin Cities Metropolitan Area.

Urban development is a growing phenomenon fueled by the need to accommodate growing populations with housing, work space and efficient means of transportation. While their development is generally a positive sign of growth and prosperity, these built environments can negatively affect the natural environment. They can decrease water quality, fish populations and groundwater reserves, and increase the likelihood of habitat fragmentation, flooding and urban heat island effects.

Research indicates that impervious surfaces - or surfaces impenetrable by water including sidewalks, driveways, rooftops and parking lots - are largely responsible for these negative environmental effects. This suggests that the amount of impervious surface area (ISA) is a good measure of environmental quality.

With the support of these findings, natural resource managers and city management have used several methods to estimate the amount of ISA at various landscape levels (e.g., local, state and regional). The outcomes of estimation procedures include maps of ISA, which serve to inform efforts to manage urban growth and minimize its impact on the environment.

Figure 1. Urban growth is creating communities such as this one. Unfortunately, their development can lead to several environmental problems which land use planners are working to address.

THE TRADITIONAL APPROACH

Impervious surface area can be measured with ground surveys and aerial photographs. Existing ground cover maps, often derived from aerial photographs, are also a spatial source of ISA.

Aerial photographs have been an important source of land use/land cover information for many years; however, the cost of acquisition and interpretation of cover types is prohibitively expensive for large geographic

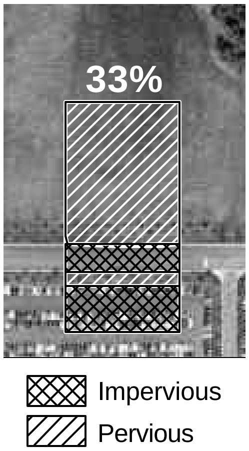


Figure 2. Sample area delineated over aerial photograph used to calculate varying degrees of ISA for model calibration and evaluation.

areas. Ground surveys are expensive and generally not practical for mapping ISA within large areas.

Once data are collected, processed and analyzed, maps are created that depict the location and often the degree of ISA. The degree of ISA refers to the percent imperviousness in a given area. The higher the percentage, the greater the environmental impact. A term such as "degraded," "impacted" or "protected" is often assigned to percentages to describe the impact of ISA on one or more natural resources. For example, Nonpoint Education of Municipal Officials uses these terms to describe the impact of ISA on water quality.

THE NEW APPROACH

Digital imagery captured from sensors on earth observing satellites, such as Landsat 5 or IKONOS-2, is another, more recent tool for estimating ISA. It offers several advantages including:

1) Synoptic coverage of small or large geographic areas
2) Land cover maps generated at considerably less cost
3) A digital format compatible with Geographic Information Systems.

Research at the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory (RSL) suggests that satellite imagery can be used to generate more affordable and accurate maps of ISA. Not only does this method have the potential to determine the presence or absence of ISA, but it can also depict the degree of imperviousness from 0 to 100%.

AN INTEGRATED APPROACH

Defining the relationship between aerial photograph measurements of ISA and spectral-radiometric responses of Landsat satellite data was key to determining whether satellite imagery would be a good candidate for creating maps of ISA.

To do so, analysts performed two tasks. First, they delineated areas on aerial photographs that represented varying degrees of ISA (Figure 2). Second, Landsat image data were converted to "greenness" - a variable that is strongly related to the amount of green vegetation (and therefore, is inversely related to the amount of ISA).

To confirm that Landsat can be used to accurately classify the percent ISA, the Landsat estimates were compared to measurements made from aerial photographs (Figure 3).

The results indicate that there is a strong relationship between aerial photograph measurements and satellite-derived estimates. With these results, analysts successfully created maps of ISA for the Twin Cities Metropolitan Area (TCMA) in Minnesota, and also larger scale maps of cities within the TCMA that are experiencing a significant amount of growth (Figure 4). Each map details land cover and the percent of ISA for urban/developed land.

The TCMA totals about 3,000 square miles and comprises seven counties with a diversity of land cover classes including high and low density urban areas, small towns, cropland, forests and wetlands.

To date, RSL analysts have used two types of satellite imagery to generate maps – moderate-resolution Landsat TM (30-meter pixels) and high-resolution IKONOS (4-meter pixels). Several dates of Landsat TM data have been evaluated for multi-county scale mapping, while two dates of IKONOS data have been evaluated for city scale mapping.

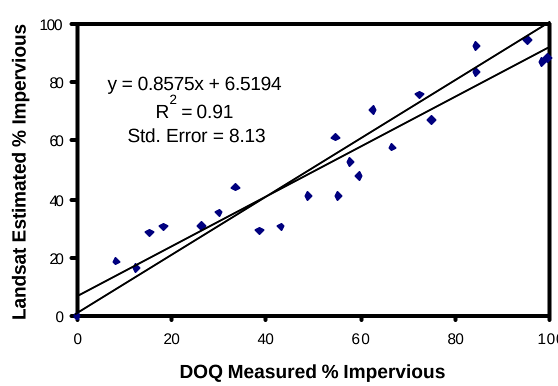
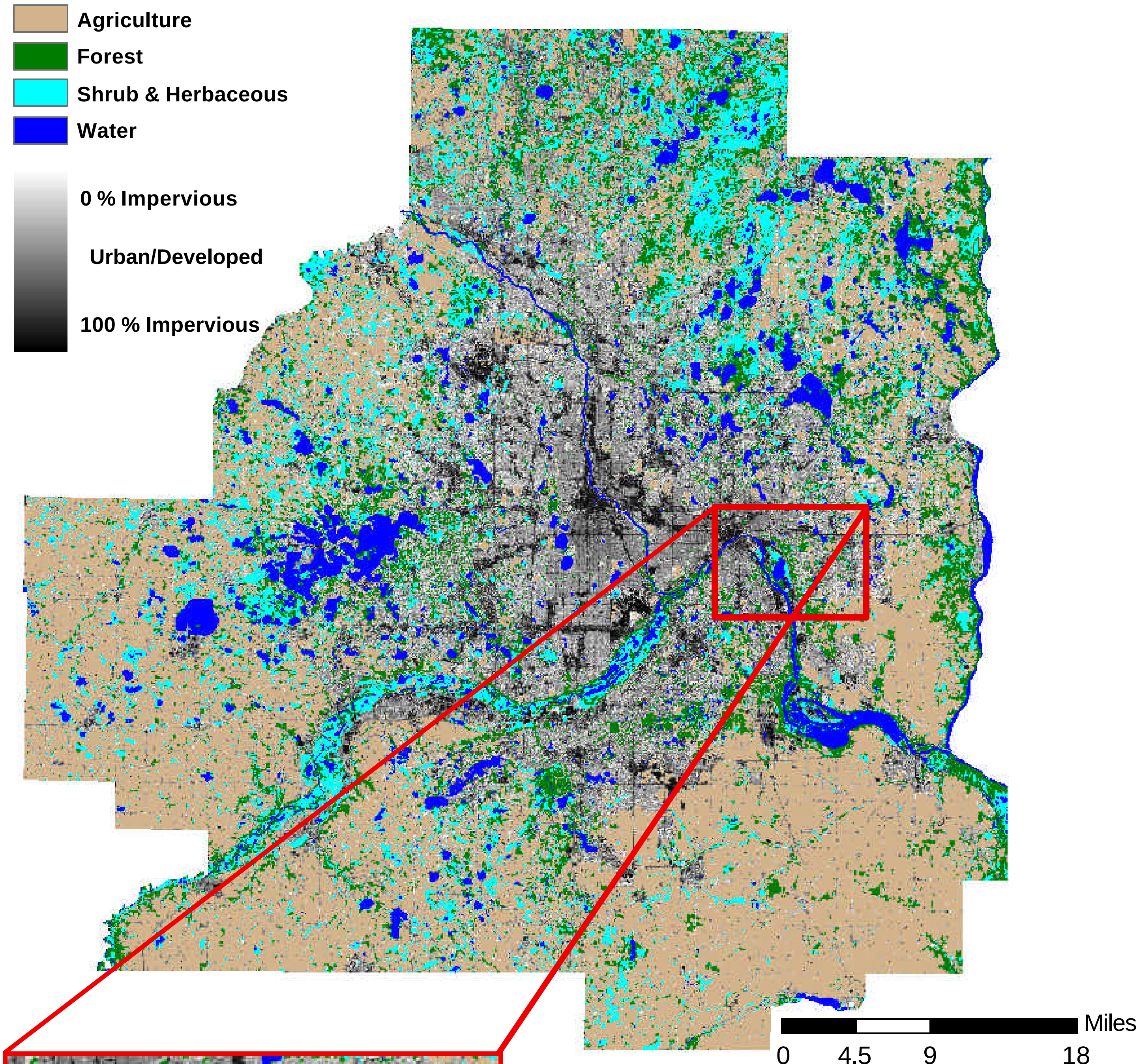


Figure 3. Comparison of aerial photograph measurements and Landsat estimates of percent impervious surface area.



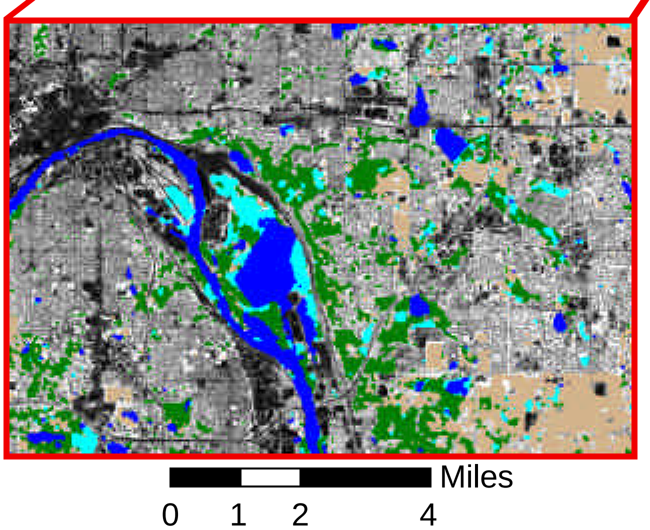


Figure 4. Maps of impervious surface area in the Twin Cities Metropolitan Area (above) and in the City of Woodbury, Minnesota (left). Each map depicts land cover and the percent of impervious surface area; one at a multi-county scale and one at a city scale. The percentage of impervious surface area is depicted as a continuous variable, ranging from 0 to 100% imperviousness based on greenness. Areas shaded in black have the highest percentage of imperviousness (low greenness), while areas shaded in white have the lowest percentage of imperviousness (high greenness). These maps were created using Landsat TM imagery from the year 2000, calibrated from aerial photograph measurements.

THE VALUE OF AN INTEGRATED APPROACH

In our efforts to apply this new method of impervious surface mapping and extend its usefulness to the public, we have worked with the Metropolitan Council, the regional planning and policy agency for the seven-county Twin Cities Metropolitan Area. Not only has this agency been a primary sponsor for this research, but they have also welcomed the opportunity to integrate project results into their everyday responsibilities in land use planning and water resource management.

Steve Kloiber, environmental analyst for the Metropolitan Council, says, "*Impervious is a very useful indicator to measure a variety of impacts of development on aquatic and terrestrial systems (increased storm water runoff, increased flooding, increased stream bank erosion, decreased habitat quality, decreased biodiversity, etc.). The satellite-based imperviousness assessment provides a cost-effective means of estimating imperviousness for large areas, such as the entire Twin Cities Metropolitan Area. In the past, this kind of data was only available for much more limited areas.*"

FURTHER READING

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UNIVERSITY OF MINNESOTA

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Metropolitan Council

The Metropolitan Council is the regional planning agency serving the Twin Cities seven-county metropolitan area and providing essential services to the region. www.metrocouncil.org

The University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory (RSL), a unit of the Department of Forest Resources and College of Natural Resources, was established in 1972 and focuses on geospatial research and development for forestry and natural resources.

Current efforts emphasize quantitative approaches to natural resource assessment, carried out in cooperation with resource agencies. Core activities at the RSL include research, education and outreach, and the facilities feature an array of hardware and software for image processing, mapping, modeling, statistical analysis and visualization.

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