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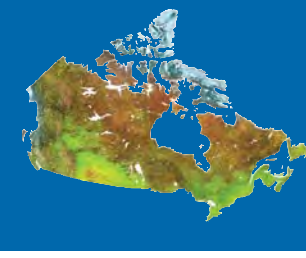

Remote sensing for improving understanding on Canadian urbanization

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Global urbanization trends present challenges, including increased energy consumption that causes air and water pollution and ecosystem degradation and local climate modification that is caused by increased heat storage and release from built structures (i.e. the urban heat island effect). The "form" of urbanized areas, i.e. their land use and demographic geospatial patterns, has significant impacts on many energy- and environment-related processes and activities conducted in urban environments.

To improve our understanding of these impacts from regional and national perspectives, the Canada Centre for Remote Sensing (CCRS) undertook initiatives to create quantitative portrayals of urban form. As a result of these initiatives, a database called the Canadian Urban Land Use Survey (CUrLUS) was created. CUrLUS contains nationally consistent urban form information that is used for assessing Canadian urban development sustainability.

CUrLUS encompasses integrated layers including land cover and land use derived primarily from satellite imagery, national population, employment and transportation statistics from the national census and other geospatial themes such as road networks. In addition, information from historical land use maps was integrated into CUrLUS. The maps were created from satellite data for the period from 1966 to 2001. Understanding of the link between urban form and urban transportation has been improved through quantification of geospatial indicators and predictive travel modelling that are based on the CUrLUS information.

Subpixel surface information extraction

In human settlement areas, pixel-level data from moderate resolution satellites such as Landsat and SPOT are primarily a mixture of land covers. The distribution of major land covers such as built-up surfaces, open lands and urban forests in metropolitan areas are key information attributes that facilitate assessing the impact of urban form on the water and air environments.

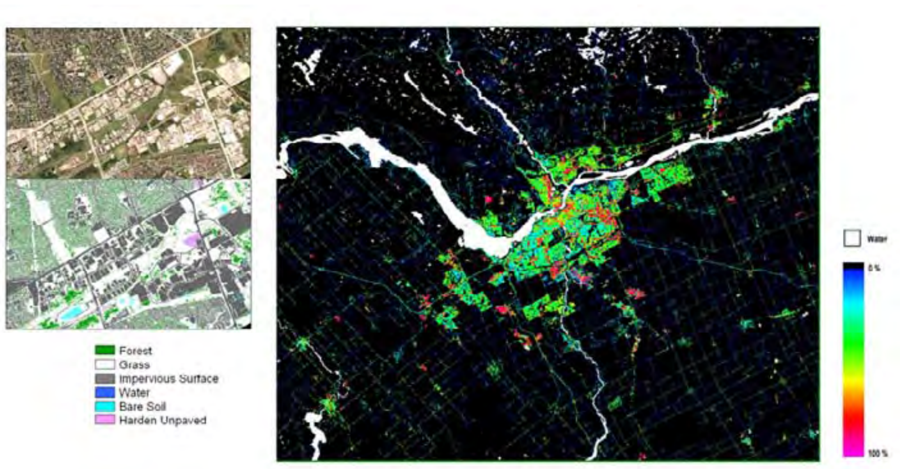
Built-up surfaces are generally impenetrable surfaces (impervious surfaces) that prevent water infiltration and include, in the urban environment, surfaces such as rooftops, roads, driveways and parking lots and compacted soil and gravels.

Quantitative understanding of the competing effects of land cover and change on the urban environment requires comprehensive characterization of the spatial distributions and changes of urban land cover densities, especially land impervious density and forest cover density.

Methods

Methodologies have been developed for mapping land cover density at the subpixel level based on integrated information from Landsat and QuickBird data. High-resolution multispectral images from the QuickBird satellite play a key role in the subpixel mapping process (see Figure 1a).

The first step is to derive a thematic classification from these data. Next, QuickBird land cover classifications (see Figure 1b) are used to "calibrate" Landsat-derived greenness.



Figures 1a and 1b. Example of a land cover map (lower left) derived from a QuickBird image (upper left) of the Ottawa-Gatineau area
Figure 1c (right). Impervious surface map of Ottawa-Gatineau area

In the next step, the CUrLUS classification for 30-metre land use and land cover is employed to provide unique calibration curves for each CUrLUS urban class. Each urban class represents unique relationships between greenness and the percentage of impervious or forest cover.

Designating an area by urban class at this point minimizes several interpretation problems, including confusion between true impervious surfaces and other non-vegetated surfaces such as fallow fields and "greenness" ambiguities between forest and herbaceous land.

The resulting subpixel impervious surface maps (see Figure 1c) and similar forest density products are portrayals of the driving and mitigating parameters of urban heating.

Measuring urban growth

Measuring urban growth and assessing its impacts require long-term records of land cover and land use change. These kinds of records cannot be obtained from a single information source. To build a consistent record, a method for assimilating such information has been developed. The method merges diverse historic information sources, and thereby reduces inconsistencies in thematic categorization and in spatial detail among the sources.

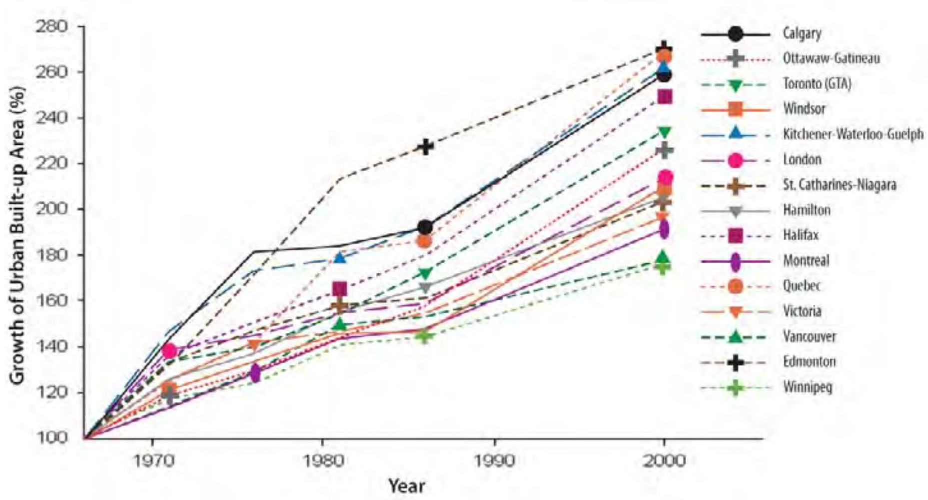


Figure 2. Relative growth in the built-up areas of major Canadian urbanized regions, 1966 to 2001

Applying this assimilation methodology has allowed the generation of consistent 35-year time series of maps that document the land cover change of major Canadian urbanized areas. Key variables that characterize the urban expansion process, such as urban land area, urban dwelling density, urban population density and natural land loss, have been estimated and examined. In addition, the influences of urban expansion on urban transportation and on the intensification of the effects of urban heat islands have been estimated by modelling case studies.

Figure 2 shows the relative growth of urban built-up areas in major Canadian urbanized regions. Overall, built-up land area increased by approximately 123 percent during the 35-year period from 1966 to 2001. Residential densities in newly developed areas in all of the major cities decreased over the same period. These trends show that low-density residential suburbanization is the dominant urban expansion process in Canada.

Urban form and urban transportation

The geospatial character of urban areas is called urban form. The spatial distributions of land use and demographics in an urban area can significantly influence its "efficiencies" in terms of energy consumption and subsequently the impact of an area on environmental and human health.

A prime example of this impact arises in transportation. North American cities are characterized by comparatively low densities and segregated land uses. These factors are reflected in high energy use per capita, which is caused by heavy reliance on using private vehicles and travelling long distances between urban areas.

CCRS and Natural Resources Canada's Office of Energy Efficiency partnered in a study to use CUrLUS information to quantify several indicators related to urban form and to evaluate the effectiveness of the indicators for monitoring Canadian urban sustainability. A novel formulation of land-use mix was developed that directly relates the level of land-use mix to travel distance and hence the feasibility of various modes of transportation. This indicator is strongly related to commuter travel effort, both at city and intra-city levels.

The Air Quality Advisory Board of the International Joint Commission assessed environmental impacts of urbanization in the Great Lakes region. A Great Lakes Urban Survey (GLUS) database was created. It is similar to CUrLUS but is international in scope because it contains consistent geospatial information on all American and Canadian cities in the basin that have populations greater than 200 000. Example travel distance maps are shown in Figure 3.

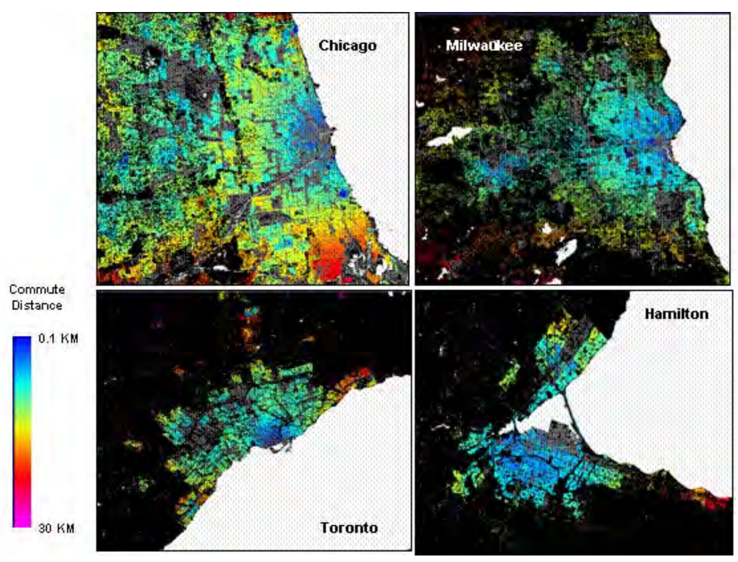
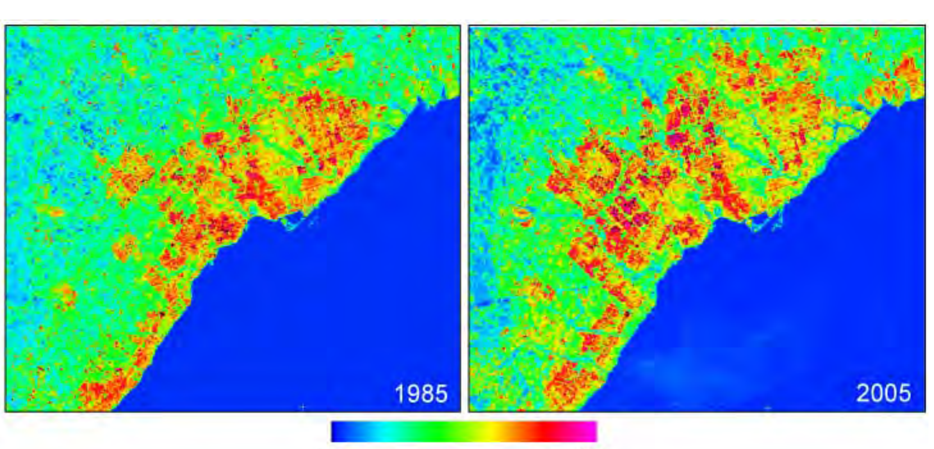


Figure 3. Travel distance maps for four urbanized areas in the Great Lakes region

GLUS is used as a source of statistics on the current state of urbanization and also to develop predictive models to investigate the impacts of alternate urban forms on surrogate measures of transportation energy consumption (travel distance). A consistent model that can be applied to both Canadian and American cities is being used in conjunction with population growth projections to assess the energy tradeoffs associated with growth options such as smart growth versus current low-density suburbanization trends.

Urban form and urban heat islands

The phenomenon of the urban heat island is caused by various physical processes and interactions among the land, air and human spheres. The form and surface fabric of urbanized areas play an essential role in causing temperature differences in urban and rural surfaces, which is called the surface urban heat island effect.



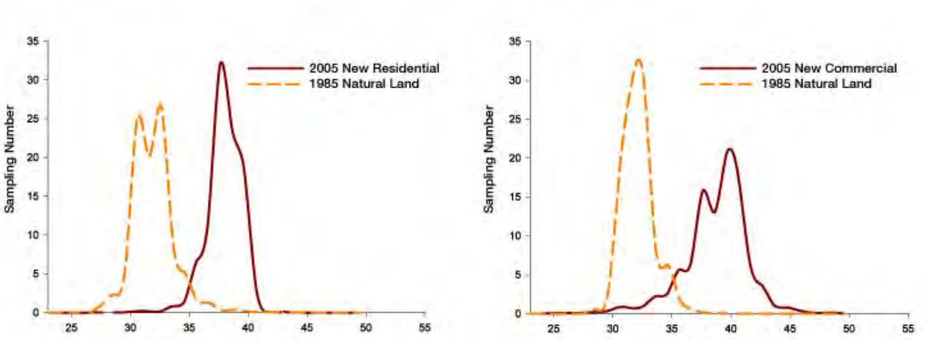


Figure 4a (upper pair). Normalized surface effective temperature distribution in Greater Toronto Area, summer 1985 (left) and summer 2005 (right).
Figure 4b (lower pair). Changes in the surface effective temperature histograms between 1985 and 2005 for new residential (left) and commercial (right) lands.

Figures 4a shows the satellite observation of intensification of the surface urban heat island in Greater Toronto Area caused by urbanization.

Figure 4b shows the increases in the surface effective temperature result from the conversion of natural land to residential (left plot) and commercial (right plot) land.

The two major Canadian urban regions of Greater Toronto and Ottawa-Gatineau were studied. Comprehensive characterizations and assessments of the relationship between the urban form and the surface urban heat island effect were done by using integrated information derived from Landsat and QuickBird satellite imagery and the demographic census. The spatial information derived includes land cover fraction maps, land use and its historic changes, surface temperature from thermal sensors, and population density maps.

Three aspects of the surface urban heat island were addressed

- the relationships between surface temperature and the three urban geospatial attributes of land use, urban land cover density and population density
- intra-city seasonal temperature variations
- the intensification of the surface urban heat island effect caused by recent urban growth

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