Urban Density

Indicator #7000

Overall Assessment

Status: **Mixed**

Trend: **Undetermined/mixed**

Rationale: **There is insufficient data on urban centres across the basin. A major challenge remains generation of consistent binational, multi-temporal statistics.**

Purpose

- To assess the urban human population density in the Great Lakes basin
- To infer the degree of land use efficiency for urban communities in the Great Lakes ecosystem

Ecosystem Objective

Socio-economic viability and sustainable development are the generally acceptable goals for urban growth in the Great Lakes basin. Socio-economic viability indicates that development should be sufficiently profitable and social benefits are maintained over the long term. Sustainable development requires that we plan our cities to grow in a way so that they will be environmentally sensitive, and not compromise the environment for future generations. Thus, by increasing the densities in urban areas while maintaining low densities in rural and fringe areas, the amount of land consumed by urban sprawl will be reduced.

State of the Ecosystem

Background

Urban density is defined as the number of people per square kilometer of land for urban use in a municipal or township boundary. Lower urban densities are indicative of urban sprawl; that is, low-density development beyond the edge of service and employment, which separates residential areas from commercial, educational and recreational areas thus requiring automobiles for transportation (TCRP 1998; TCRP 2003; Neill *et al*. 2003). Urban sprawl has many detrimental effects on the environment. The process consumes large quantities of land, multiplies the required horizontal infrastructure (roads and pipes) needs, and increases the use of personal vehicles while the feasibility of alternate transportation declines. When there is an increased dependency on personal vehicles, an increased demand for roads and highways follows, which in turn, promotes segregated land uses, large parking lots, and urban sprawl. These implications result in the increased consumption of many non-renewable resources, the creation of impervious surfaces and damaged natural habitats, and the production of many harmful emissions. Segregated land use also increases the average time spent traveling and reduces the sense of community, derived from public interaction.

A number of factors need to be taken into account when assessing urban density. First, urban areas are complex and density alone encapsulates only place of residence demographics and not employment attributes. Second, while a primary focus has been on viewing high density as desirable (e.g. to combat the detrimental aspects of sprawl such as automobile dependence, land use pressures, etc), there are potential costs associated with this goal such as congestion, enhance urban heating, quality of life, etc).

This indicator offers information on the presence, location, and predominance of human-built land cover and infers the intensity of human activity in the urban area. It may provide information about how such land cover types affect

the ecological characteristics and functions of ecosystems, as demonstrated by the use of remote-sensing data and field observations.

Status of Urban Density

Within the Great Lakes basin there are 10 Census Metropolitan Areas (CMAs) in Ontario and 24 Metropolitan Statistical Areas (MSAs) in the United States. In Canada, a CMA is defined as an area consisting of one or more adjacent municipalities situated around a major urban core with a population of at least 100,000. In the United States, an MSA must have at least one urbanized area of 50,000 or more inhabitants and at least one urban cluster of at least a population of 10,000 but less than 50,000. The urban population growth in the Great Lakes basin shows consistent patterns in both the United States and Canada. The population in both countries has been increasing over the recent decades. According to the Statistics Canada reports, between 1996 and 2006, the population of the Great Lakes basin CMAs grew from 7,041,985 to 8,187,945, an increase of 1,145,960 or 16.27% in 10 years. The 2000 U.S. census reports that from 1990 to 2000 the population contained in the MSAs of the Great Lakes basin grew from 26,069,654 to 28,048,813, an increase of 1,979,159 or 7.6% in 10 years.

In the Great Lakes basin, while there has been an increase in population, there has also been an increase in the average population densities of the CMAs and MSAs. However, using the CMA or MSA as urban delineation has two major limitations. First, CMAs and MSAs contain substantial rural land areas and by themselves result in over-estimation of the land area occupied by a city or town. Second, these area delineations are based on a population density threshold and hence provide information on residential distribution and not necessarily on other urban land categories such as commercial or recreational land. If within the CMAs and MSAs the amount of land being developed is escalating at a greater rate than the population growth rate, the average amount of developed land per person is increasing. For example, "In the Greater Toronto Area (GTA) during the 1960s, the average amount of developed land per person was a modest 0.019 hectares (0.047 acres). By 2001 that amount tripled to 0.058 hectares per person (0.143 acres)" (Gilbert *et al*. 2001).

While density is a readily understandable measure, it is challenging to quantify because of the difficulty in estimating true urban extent in a consistent and unbiased way. The political geographic extents of MSAs and CMAs give approximate indications of relative city size. However, they tend to contain substantial areas of rural land use. Recently, satellite remote sensing data has been used to map land use of Canadian cities as part of a program to develop an integrated urban database, the Canadian Urban Land Use Survey (CUrLUS). In southern Ontario, a total of 11 cities have been mapped (using Landsat data acquired in the 1999 to 2002 timeframe) and their densities estimated using population statistics from the 2001 Canadian census (Figure 1). Population density tends to correlate positively with the city size. Comparing the population densities of 11 cities (or CMAs) in southern Ontario, derived from remote sensing mapping and 2001 census (Zhang and Guindon 2005), the Greater Toronto Area (GTA) has a higher population density (2848 people /km^2, 7376 people/$mile^2$) than other smaller cities.

The growth characteristics of five large Canadian cities have also been studied for the period from 1986 to 2000. Preliminary analyses (Figure 2) indicate the areal extents of these communities have grown at a faster rate than their populations and thus that sprawl continues to be a major problem.

A comparison of the ten CMAs and MSAs with the highest densities to the ten CMAs and MSAs with the lowest densities in the Great Lakes basin shows there is a large range between the higher densities and lower densities. Three of the ten lowest density areas have experienced a population decline while the others have experienced very little population growth over the time period examined. The areas with population declines and areas of little growth are generally occurring in northern parts of Ontario and eastern New York State. Both of these areas have had

relatively high unemployment rates (between 8% and 12%) which could be linked to the slow growth and decreasing populations.

Over the past two years progress has been made to further address the need for baseline urban information. A Great Lakes urban database, the Great Lakes Urban Survey (GLUS) has been assembled that provides quantitative information on the state of urban form of the 22 MSAs/CMAs (Table 1) in the region with populations in excess of 200,000 (circa 2000 epoch). A fundamental information layer of GLUS is land cover / land use derived in part from Landsat satellite data. This information provides a precise estimate of urban land in each MSA/CMA, a perquisite for accurate density estimation. Additional layers include census tract level information on population, employment and work-related travel statistics. Figure 3 summarizes urban density estimates for these 22 centres.

There are number of points to note including (a) a distinct density differences between U.S. and Canadian urban areas and (b) an apparent trend, strong among Canadian CMAs and weaker among U.S. MSAs of increasing density with population. While it is important to monitor growth of large cities, it is imperative that surrounding regions need to be monitored to account for the extensive development of recreational areas (e.g. 'cottage country') as well smaller urban centres that have become attractive retirement communities.

Pressures

Under the pressure of rapid population growth in the Great Lakes region, mostly in the metropolitan cities, urban development has been undergoing unprecedented growth. For instance, the urban built-up area of the GTA has doubled since 1960s. Sprawl is increasingly becoming a problem in rural and urban fringe areas of the Great Lakes basin, placing a strain on infrastructure and consuming habitat in areas that tend to have healthier environments than those that remain in urban areas. This trend is expected to continue, which will exacerbate other problems, such as increased consumption of fossil fuels, longer commute times from residential to work areas, and fragmentation of habitat. For example, at current rates in Ontario, residential building projects will consume some 1,000 km^2 (386 $mile^2$) of the province's countryside, an area double the size of Metro Toronto, by 2031. Also, gridlock could add 45% to commuting times, and air quality could suffer due to a 40% increase in vehicle emissions (Loten 2004). The pressure urban sprawl exerts on the ecosystem has not yet been fully understood. It may be years before all of the implications have been realized.

Management Implications

Urban density impacts can be more thoroughly explored and explained if they are linked to the functions of ecosystems (e.g., as it relates to surface water quality). For this reason, interpretation of this indicator is correlated with many other Great Lakes indicators and their patterns across the Great Lakes. Urban density's effects on ecosystem functions should be linked to the ecological endpoint of interest, and this interpretation may vary as a result of the specificity of land cover type and the contemporaneous nature of the data. Thus, more detailed land cover data are required.

To conduct such measures at a broad scale, the relationships between land cover and ecosystem functions need to be verified. This measure will need to be validated fully with thorough field-sampling data and sufficient *a priori* knowledge of such endpoints and the mechanisms of impact (if applicable). The development of indicators (e.g., a regression model) is an important goal, and requires uniform measurement of field parameters across a vast geographic region to determine accurate information to calibrate such models.

The governments of the United States and Canada have both been making efforts to ease the strain caused by pressures of urban sprawl by proposing policies and creating strategies. Although this is the starting point in

implementing a feasible plan to deal with the environmental and social pressures of urban sprawl, it does not suffice. Policies are not effective until they are put into practice, and, in the meantime, our cities continue to grow at unsustainable rates. In order to mitigate the pressures of urban sprawl, a complete set of policies, zoning bylaws and redevelopment incentives must be developed, reviewed and implemented. As noted in the Urban Density indicator report from 2000, policies that encourage infill and brownfields redevelopment within urbanized areas will reduce sprawl. Compact development could save 20% in infrastructure costs (Loten 2004). Comprehensive land use planning that incorporates transit, while respecting adjacent natural areas, will help alleviate the pressure from development.

For sustainable urban development, we should understand fully the potential negative impacts of urban high density development. High urban density indicates intensified human activity in the urban area, which could produce potential threats to the quality of the urban environment. Therefore, the urbanization strategies should be based on the concept of sustainable development with a balance of the costs and benefits.

Comments from the author(s)

A thorough field-sampling protocol, properly validated geographic information, and other remote-sensing-based data could lead to successful development of urban density as an indicator of ecosystem function and ecological vulnerability in the Great Lakes basin. This indicator could be applied to select sites, but would be most effective if used at a regional or basin-wide scale. Displaying U.S. and Canadian census population density on a GIS-produced map will allow increasing sprawl to be documented over time in the Great Lakes basin on a variety of scales. For example, the maps included with the 2003 Urban Density report show the entire Lake Superior basin and a closer view of the southwestern part of the basin.

To best quantify the indicator for the whole Great Lakes watershed, a watershed-wide consistent urban built-up database is needed.

Assessing Data Quality

Insert “x” under the statement that best corresponds with each data characteristic

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization		X				
2. Data are traceable to original sources		X				
3. The source of the data is a known, reliable and respected generator of data		X				
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin		X				
5. Data obtained from sources within the U.S. are comparable to those from Canada		X				
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report		X				

Clarifying Notes:

Acknowledgments
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Ying Zhang, Natural Resources Canada, Ottawa, ON
Ric Lopez, U.S. Environmental Protection Agency, Las Vegas, NV (2006)
Lindsay Silk, Environment Canada Intern, Downsview, ON (2004)

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U.S. Census Bureau. American Fact Finder, Census 2000 Summary File 1 (SF 1) 100-Percent Data, Detailed Tables http://factfinder.census.gov/servlet/DTGeoSearchByRelationshipServlet?_ts=109848346281. *[Editor's note: If link to data is inoperative, navigate to "Data Sets" via American FactFinder at,* http://factfinder.census.gov/*]*

Y. Zhang and B. Guindon, 2005. Using satellite remote sensing to survey transportation-related urban sustainability. Part I: Methodology for indicator quantification. *International Journal of Applied Earth Observation and Geoinformation*, 8(3):149-164.

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CMA/MSA	Population	CMA/MSA	Population
Chicago-Gary, IL/IN	9,157,540	Kalamazoo-Battle Creek, MI	452,851
Detroit-Ann Arbor-Flint, MI	5,456,428	Lansing-East Lansing, MI	447,728
the Greater Toronto Area, ON	4,682,897	London, ON	432,451
Cleveland-Akron, OH	2,945,831	Kitchener-Waterloo, ON	414,284
Milwaukee-Racine, WI	1,689,572	Saginaw-Bay City, MI	403,070
Buffalo-Niagara Falls, NY	1,170,111	St. Catharines-Niagara Falls, ON	377,094
Rochester, NY	1,098,201	Windsor, ON	307,877
Grand Rapids-Muskegon-Holland, MI	1,088,514	Oshawa, ON	296,298
Syracuse, NY	732,117	Erie, PA	280,843
Hamilton, ON	662,401	South Bend, IN	265,559
Toledo, OH	618,203	Green Bay, WI	226,778

Table 1. Great Lakes urban areas with populations in excess of 200, 000 (based on 2000 U.S. and 2001 Canadian census data).
Source: U.S. Census Bureau, 2000 and Statistics Canada, 2001

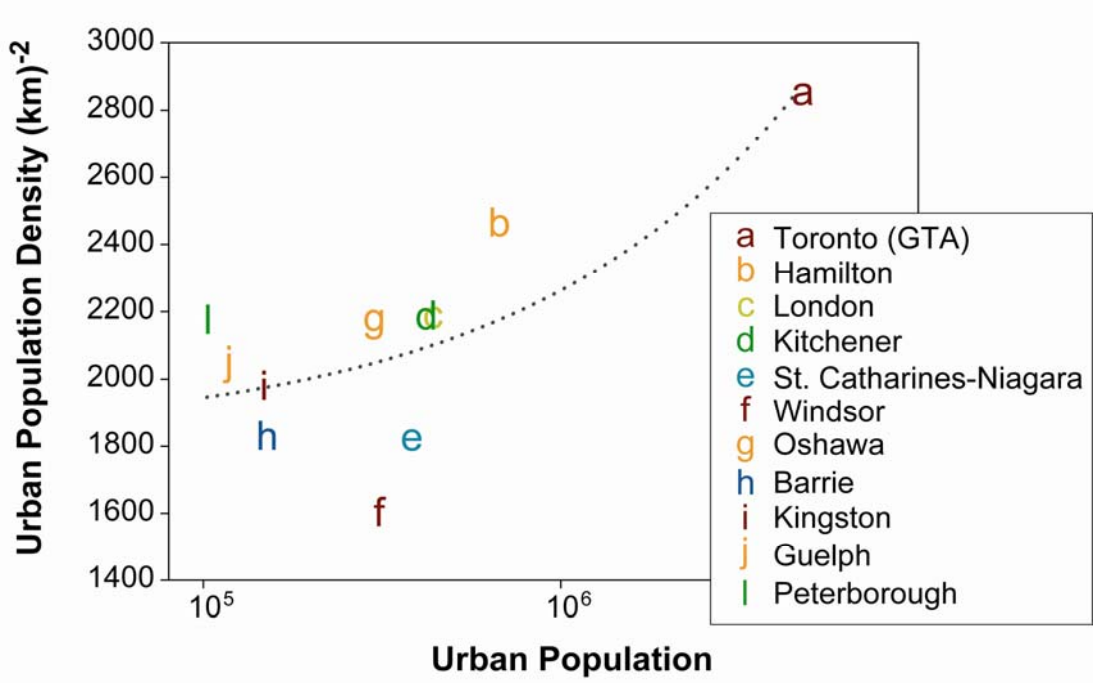

Figure 1. Population densities of cities with populations more than 100,000 in southern Ontario of the Great Lakes watershed for 2001.
Source: Y. Zhang and B. Guindon, private communication

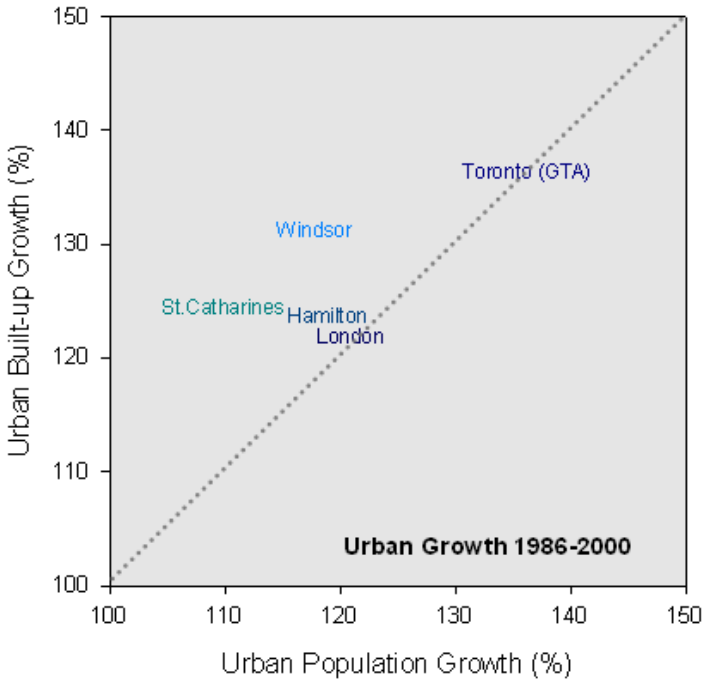

Figure 2. Growth characterization of 5 urban areas in the period of 1986-2000.
Source: Y. Zhang and B. Guindon, private communication

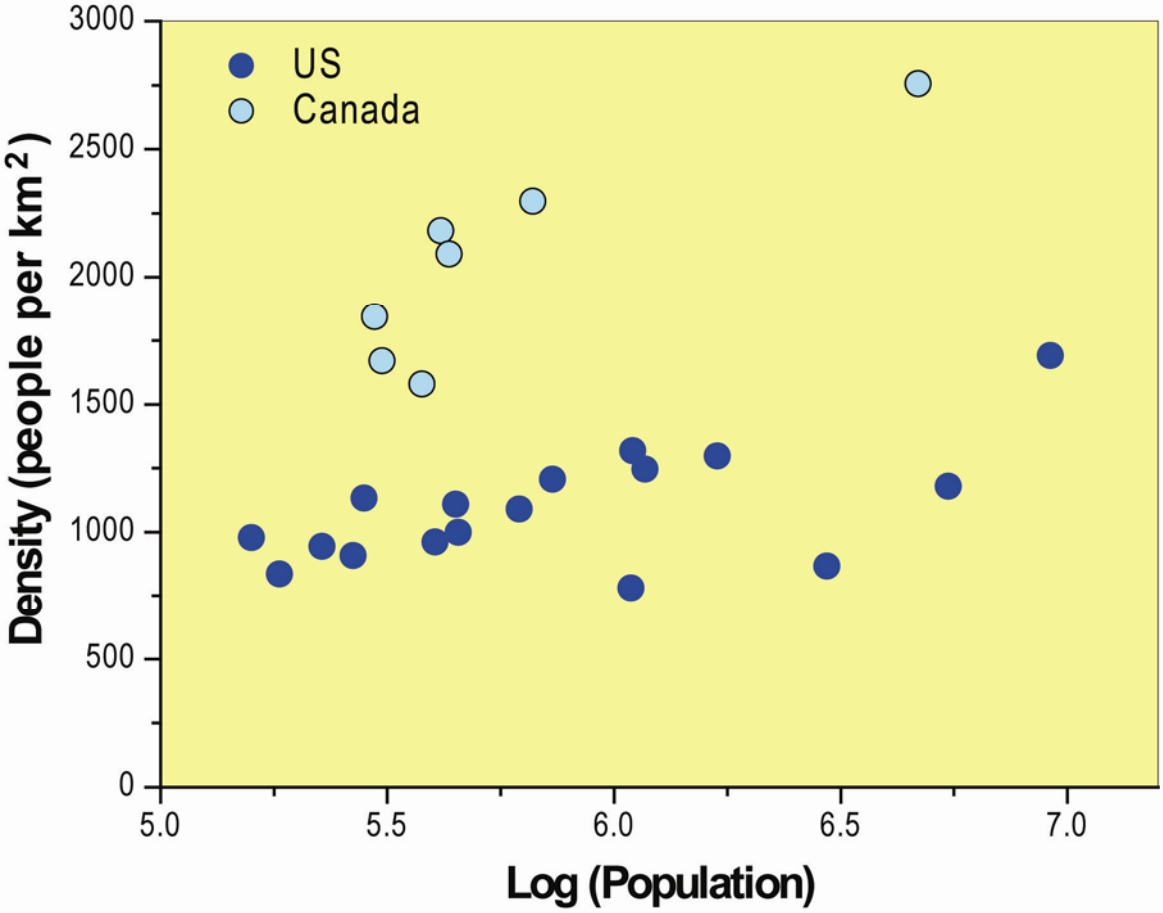

Figure 3. Urban density vs population for 22 MSAs and CMAs.
Source: B. Guindon and Y. Zhang, private communication