Stadtentwicklung in Calgary, Toronto, und Vancouver: Interpretation mit Landsatdaten [1]

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Abstract (Zusammenfassung)

This research examines urban growth and renewal in three larger metropolitan centres in Canada (Calgary, Toronto, and Vancouver). These cities have seen various rates of growth from the 1970's to present, which can be related to population changes observed in Canadian Census data. A combined unsupervised classification (ISOCLUS option) and Normalized Difference Vegetation Index (NDVI) subtraction method is used to determine urban change. The results for Toronto from 1974 to 2001 indicate a total urban "built" area change of approximately 247 km^2 or 9.15 km^2 per year. It is possible to successfully utilize the Landsat satellite image archive and current observations to monitor trends in city development over time.

1 Introduction

1.1 The Landsat Program

The year 1972 marked the beginning of the era of civilian space-based remote sensing with the launch of the first Earth Resources Technology Satellite (ERTS-1, later renamed Landsat 1). The Landsat program has provided the remote sensing and other user communities with a large and continuous archived imagery record. The majority of these data are available on the Internet via the Earth Explorer web interface (http://edcsns17.cr.usgs.gov/EarthExplorer/), maintained by the United States Geological Survey (USGS) Earth Resource Observation Systems (EROS) Data Centre. A total of seven Landsat satellites have been launched (Tabelle 1). The major goal of the Landsat program has been to track land cover changes (MASEK et al., 2000) or as LAUER et al. (1997) state: to discriminate, identify, categorize, and map the Earth's features and landscapes based on their spectral reflectances and emissions.

The instruments used to collect data onboard Landsat satellites have varied throughout the course of the program. Landsat's 1-3 contained a Return Beam Vidicon (RBV) "camera" as well as a Multispectral Scanner (MSS) instrument. The MSS was onboard Landsat's 1-5 and with the launch of Landsat 4, a new instrument, the Thematic Mapper (TM) was

[1] Preliminary classification results for Toronto are presented in the proceedings version of this paper. The results for Calgary and Vancouver (together with Toronto) will be presented at the conference.

introduced. With the launch of Landsat 7, the latest device came into service, the Enhanced Thematic Mapper (ETM+) (LAUER et al., 1997). There has always been some continuity with respect to the portions of the spectrum where data have been collected since the beginning of the Landsat program. This allows for the historical comparison of datasets over time.

Tab. 1: Landsat Satellite History and Status (Source: after LAUER et al., 1997)

Satellite	Launched	Status
Landsat 1	July 1972	decommissioned 1978
Landsat 2	January 1975	decommissioned 1982
Landsat 3	March 1978	decommissioned 1983
Landsat 4	July 1982	data transmission problems (standby mode)
Landsat 5	March 1984	still collecting and transmitting data to ground stations
Landsat 6	October 1993	failed to achieve orbit
Landsat 7	April 1999	collecting and transmitting data to ground stations

1.2 Urban Environments and Urban Remote Sensing

The present urban population is estimated to be 3.2 billion (half of the worlds population), and it increases by an average of 1 million people per week (CHEN et al., 2000). A move to urban centres is occurring in both developed and developing nations. The large amount of growth associated with these population shifts strains the resources of cities. Urbanization is one aspect of critical importance to the human occupants of the earth that is poorly measured (MASEK et al., 2000). Regional land cover changes brought about by human activity tend to occur incrementally, and it can be difficult for communities to realize the extent of their development and therefore, the changes in their environment (ARTHUR et al., 2000).

Remote sensing has traditionally concentrated on rural or natural areas when looking at land use change. There has however been a recent trend toward the analysis of urban environments (ARTHUR et al., 2000; CHEN et al., 2000; MASEK et al., 2000; YEH and LI, 2001). Using image radiometry is the best method to determine urban change (RIDD and LIU, 1998; MASEK et al., 2000). With most image analysis applications, the goal is to produce classified end products through either supervised or unsupervised methods. The problem with using either of these methods over a time-series of imagery is that the classification errors will propagate over the length of the analysis period. It is therefore more efficient to directly use radiometry, which should be relatively constant if the image acquisition dates are consistent (eg. year to year) and the data are from the same satellite platform.

The methods of radiometric analysis include: band-by-band image differencing, image ratioing, change vector analysis, and vegetation index differencing. JENSEN and TOLL (1982, as found in MASEK et al., 2000) were able to detect with reasonable accuracy, the urban growth of Denver, Colorado using Landsat MSS (Band 5) data. RIDD and LIU (1998) utilized similar techniques with Landsat TM data (Band 2) and found that they produced a much more accurate account of urban land cover change. MASEK et al. (2000) used MSS and TM data in a Normalized Difference Vegetation Index (NDVI) subtraction approach for successful urban change detection.

1.3 Urban Trends in Canada

The Canadian Census is conducted on a 5-year cycle. The latest numbers (for 2001) indicate that the trend towards increasing urbanization continues in Canada. Some of the highlights of the 2001 census when compared to the 1996 census were:

- Canada's population grew by approximately 4 percent to over 30 million
- 51 percent of Canadians live in southern Ontario's Golden Horseshoe (including Toronto), the Montreal (Quebec) area, British Columbia's lower mainland (including Vancouver), and the Calgary-Edmonton corridor in Alberta (CBC, 2002).
- 79.4% of Canadians lived in an urban centre of 10000 or more (STATISTICS CANADA, 2002).

2 Study Area and Data

The major cities that are currently experiencing the fastest population growth rates in Canada are: Calgary, Toronto, and Vancouver (STATISTICS CANADA, 2002). These cities have seen various rates of growth from the 1970's to present and this is assessed using Landsat satellite imagery. The growth of Toronto and Vancouver has occurred in part through increased immigration, while Calgary has seen population increases to a great extent as a result of migration from other parts of Canada (STATISTICS CANADA, 2002). In order to provide a comparison between the three cities and their growth rates, nine images (3 for each city) were selected (Tabelle 2).

Tab. 2: Date and Type of Landsat Satellite Images Used in Analysis

Calgary	Toronto	Vancouver
1979-06-28 MSS	1977-06-11 MSS	1978-06-02 MSS
1992-08-14 TM	1990-09-02 TM	1991-08-15 TM
2000-08-28 ETM+	2000-08-20 ETM+	2000-07-30 ETM+

3 Data Preparation, Analysis, and Results

Landsat imagery was selected for two main reasons: (1) it is the longest running continuous civilian satellite data archive (1972 to present), and (2) it is low in cost when compared to other satellite data. A time-series imagery file has been developed for each city. These were however subset due to computer storage, memory, and performance issues.

A combined radiometry and classification method was used to assess urban change. NDVI images were calculated for each image acquisition date and then subtracted (newer minus older) to determine areas where the NDVI had changed dramatically. Normally, areas where high NDVI values were replaced with low NDVI values are change areas. This must however be tempered with the fact that crop rotation can have similar effects on NDVI values (GRIFFITHS, 1988 as found in MASEK et al., 2000). To address this concern, the ISOCLUS (PCI, 2001) unsupervised classification procedure was performed on each image to identify urban, green space, and water areas. The classified images served as an urban proximity measure so that change areas identified by NDVI differencing (subtraction) could be distinguished as being either true urban change or normal crop rotation.

Urban built area change (Abb. 1) was determined after the datasets were exported from the PCI Geomatica image processing software to the ArcView Geographic Information System (GIS). Built areas are defined in this paper as non-natural features put into place through human activities. The calculations for built area and specifically built area change correspond quite well with data obtained from the Canadian Census. There is however one period in the imagery record (1977 to 1985), which is quite long. During this time period, the urban expansion of the late 1970's masks the effects of the recession of the early 1980's (1980-1982) (CMHC, 2000). It is however possible to see the effects of the 1990-1992 economic slowdown on the growth rates for the 1986-1991 and 1991-1996 census periods. The satellite-based estimates of urban built area change for Toronto from 1974 to 2001 indicate a total area change of approximately 247 km^2 (Abb. 2) or 9.15 km^2 per year.

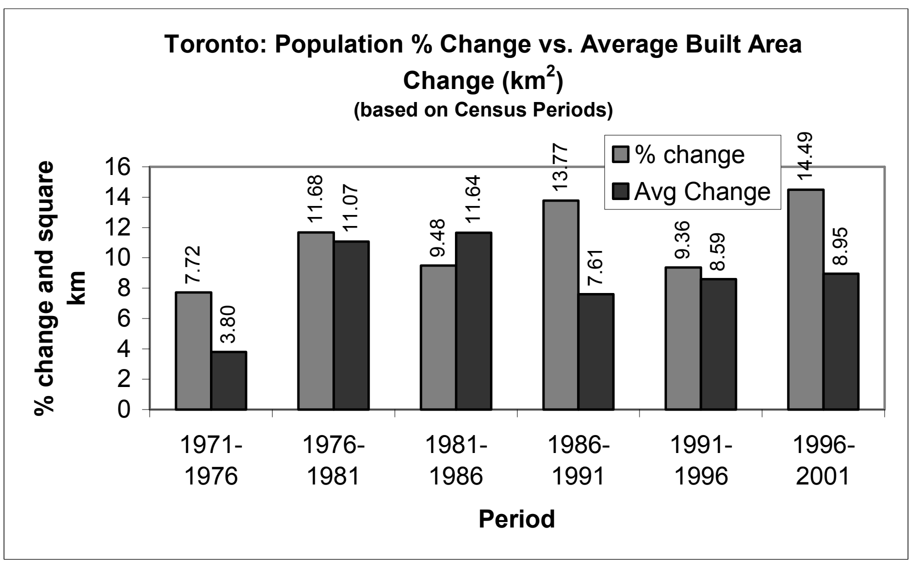

Abb. 1: Toronto: Population Percent Change vs. Average Built Area Change (based on Census Periods)

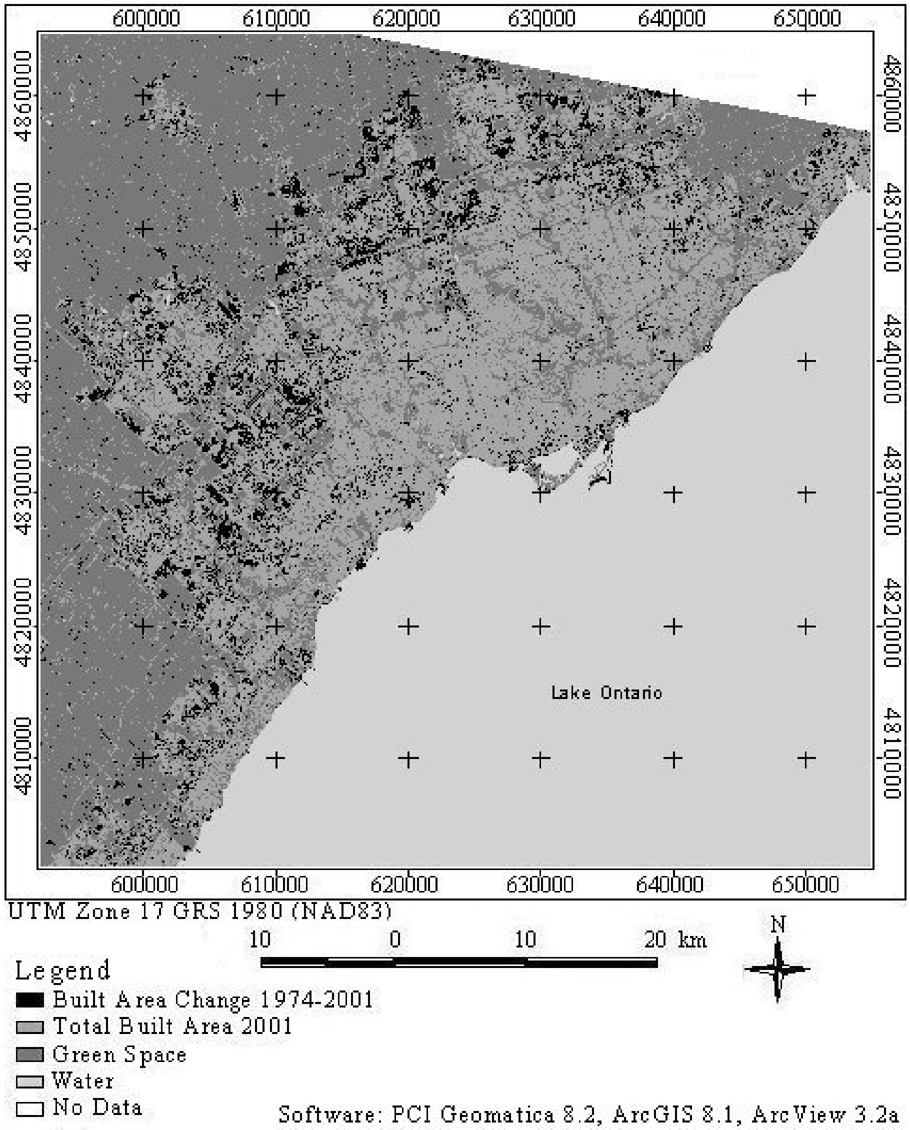

Abb. 2: Built Area Change in the Toronto Area (1974-2001)

4 Conclusion

The spatial resolution of the Landsat images is sufficient for mapping urban development. Landsat satellite imagery can be used to produce accurate estimates of urban growth. These estimates can be related to census and economic data that are available from traditional data sources. One of the main advantages of this approach is its low cost as compared to traditional mapping techniques. The data that are produced can be easily exported to GIS packages where additional analyses can be performed. The digital data that are produced also have advantages over other types of analogue data where lengthy conversion and/or import processes may be necessary.

It would be ideal if satellite images could be obtained for each census or other time period being analyzed. The possibility for this exists in the future with the image acquisition program planned for Landsat 7 and through the use of the Landsat archive. There are many opportunities for geographers, urban planners, and others to take advantage of the image information available from the Landsat archive.

5 References

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