Chapter 20
Analysing Land Use Transformation and Water Security: Evidence from the Global North and the Global South

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Abstract The chapter investigates the pattern of land use transformation and water security in cities from the global north and the global south. The study considers Toronto and National Capital Territory Delhi (NCT Delhi) to investigate the approach and pattern of urban water management to meet the water demand with the changing land use transformation and built form intensification. The chapter also recognises the different contexts and challenges experienced by the cities of the two hemispheres. The motivation for the study comes with the global recognition of water as a crucial resource for human sustenance and the opportunity to learn between the global north and south through a case study approach.

Keywords Land use transformation · Spatio-temporal analysis · Water security · Built form intensification · Rapid urbanisation · Groundwater

Introduction

The rate of urbanisation has experienced a rapid increase in the past 50 years across the globe. The United Nations (UN) has estimated that by the year 2050, 68% of the world's population will live in urban areas (Ritchie 2018). This rapid urbanisation results in a rapid transformation of land use affecting the infrastructure demand and consumption patterns. This study considers two regions, i.e. Toronto and National

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U. Chatterjee et al. (eds.), *Urban Commons, Future Smart Cities and Sustainability*, Springer Geography, https://doi.org/10.1007/978-3-031-24767-5_20

Capital Territory Delhi (NCT Delhi), to explore the urban water security and urban water management during land use transformation and built form intensification.

Rapid urbanisation took place at the beginning of the nineteenth century and continued throughout the twentieth century in Canada. Canada's three largest census metropolitan areas (CMAs)—Toronto, Montreal and Vancouver—cover one-third of its population. In 2018, almost 26.5 million people were living in the CMAs (Statistics Canada 2019). In India, steady urbanisation took place with a small growth in the urbanisation trend at the beginning of the twentieth century. The population is increasing in Hyderabad, Bengaluru, Chennai and Delhi and decreasing in Mumbai and Kolkata (Census of India 2011). In 2019, the annual population growth of India and Canada was 1.42% and 1.01%, respectively.

With this pace of urbanisation, the core infrastructure facilities are under continuous stress. Water, one of the most significant resources of the planet, needs to be managed appropriately to ensure a sustainable future for these megacities. The two cities are selected, i.e. Toronto and NCT Delhi, from the global north and the global south, to assess and compare the impact of rapid urbanisation on water security and how the cities address the water security issues. Toronto and Delhi are two important cities in their respective region and faces extreme challenges from rising urbanisation, pollution, land use transformation, and threats of climate change. The local and regional administrations of both cities work hard to achieve water security and meet the desired water quality standard. While Toronto is very particular about maintaining its water adequacy with proper planning and management, NCT Delhi struggles to secure a stable water supply for its citizen. A comparative study from one of the populous cities of the global north will be extremely important for Delhi to comprehend the approach and methods of creating water secured city. This study analyses the water consumption patterns of both cities and the changes in land use dynamics. The research contributes towards a deeper understanding of how the geography and socio-demography of the cities in distinct locations affect water consumption. The objectives of the research are:

i. to study the background and demography of Toronto and NCT Delhi;
ii. to assess the land use land cover change in these cities in the past two decades; and
iii. to analyse the water security and water adequacy.

Section Introduction discusses the background of urbanisation over the past decades and compares the two at the country level. The remaining chapter consists of seven sections. Section Literature Review includes the literature review from the previous research on Toronto and NCT Delhi on spatio-temporal and land use land cover changes. Sections Study Areas and Demographic Profile—A Comparison discuss the two study areas and compare their respective demographic profiles. Section Spatio-Temporal Changes—A Comparison compares the spatio-temporal changes through the mapping of land use and land cover changes over the past two decades. Sections Water Management in Toronto and Water Management in NCT Delhi discuss the water management status in Toronto and NCT Delhi and the conservation measures suggested and implemented by the respective regulating authorities.

Finally, Sect. Discussion and Conclusion the chapter with the final arguments and a summary of the analysis.

Literature Review

The Greater Toronto Area (GTA) comprises the regions like York, Halton, Durham, Peel, Hamilton, and the City of Toronto. Toronto is the biggest metropolitan area of the Greater Toronto Area and experiencing a gradual growth of population compared to other cities. Toronto is the most populous city in the region and achieved a point of population saturation. Therefore, the increase in population is not prominent as compared in other areas.

Wang (2015) mapped the urban growth of Toronto from the year 1974–2014. The imageries from Landsat 1 and 2 (Multi-spectral scanner), Landsat 5 (Thematic mapper), Landsat 7 (Thematic mapper plus) and Landsat 8 (Operational lands imager) were used as the main datasets for the input. The imageries were acquired from the United States Geological Survey's (USGS) Landsat Data Archive (Wang 2015). The city of Toronto consists of various types of land cover such as lakes and rivers, highly dense urban areas, and the rural area along with agricultural land, forests. The multi-spectral change detection for the period 1974–2014 helped to assess the growth and expansion pattern in Toronto.

Figure 20.1 visually analyses the temporal growth of the built-up area of the GTA. The analysis suggests a radiated expansion of built forms from the urban centres, especially in the city of Toronto. The GTA also expanded like a ribbon along Lake Ontario. The increase in population was strongly correlated to the urban expansion of the area.

The most significant expansion was observed between 1984–89 and 1999–2004, with an annual growth rate of 4.3% and 3.6%, respectively. The negative trend in early 1974–79 could be due to the error of poor data acquired by Landsat 1. The expansion in the period 2004–2009 is only recorded to be 0.1%. We argue that the decrease in population growth percentage is due to the population saturation of the GTA. The urban expansion in the subsequent period is delayed by the notable population increase in the previous years as the city prepares for its infrastructure needs (Wang 2015). In the case of Toronto, the city was well urbanised in the late twentieth century. The downtown area of the city of Toronto was the main focal point of urban expansion and influenced the growth in the surrounding regions.

Dutta and Rahman (2017) record the urban growth and the land use and land cover changes in Delhi between 1977–2014 (Dutta and Rahman 2017). The study uses the satellite imageries of Landsat 1 and 2 (Multi-spectral scanner), Landsat 5 (Thematic mapper) and Landsat 8 (Operational lands imager) during the winter season (February–March) to avoid cloud cover in the imageries for better analysis. The pre-processing of Landsat data was done in 1977, 2003 and 2014. The field observation is then accurately assessed and compared with the pre-processing and classification results to obtain urban growth analysis in NCT Delhi.

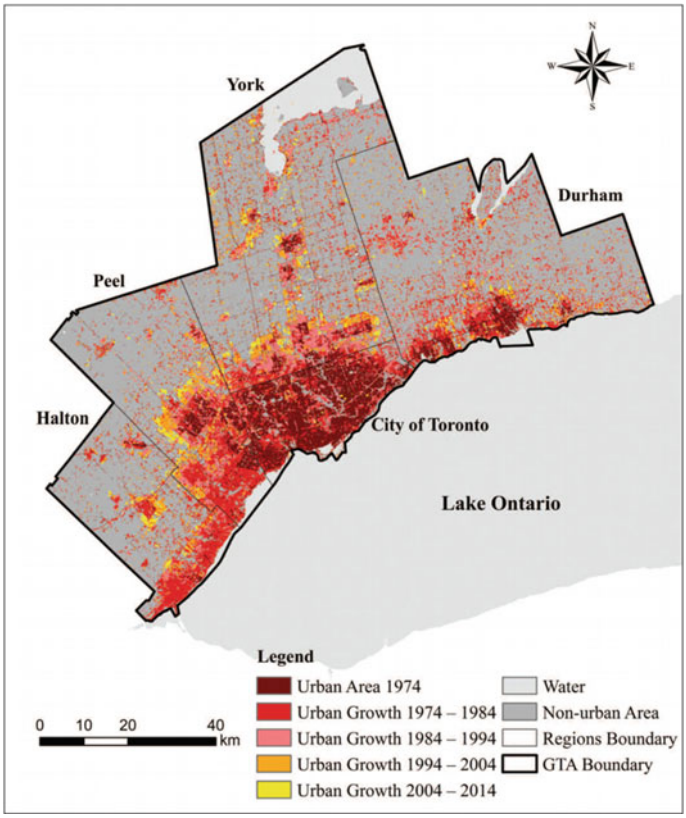


Fig. 20.1 Multi-temporal change detection from 1974 to 2014 (Wang 2015)

In 1977, agricultural land use was predominant, along with the patches of high-density built-up areas and sparse vegetation. High-density built-up areas are mostly observed in Central Delhi and East Delhi along the river Yamuna. In 2003, the built-up areas were densified in the North-West and Southern areas. An increase in sparse vegetation can be observed along with the development of low-density built-up areas in the east. The dense vegetation during 1977–2003 has also decreased subsequently. In 2014, a sharp increase in high-density built-up areas can be observed in the core area and in the Southern areas. The dense vegetation has also increased from the earlier observation period in 2003.

The quantum of land use change can be observed in terms of the percentage change of each class during the two consecutive periods in Table 20.1. In 1977–2003, the change in built-up areas was recorded as 7.16%, and the decrease in sparse vegetation by about 12.2%. The decrease in vegetation is reciprocal for accommodating more built-up areas during this period A sharp increase of almost 20% was observed from 2003 to 2014, accompanying the decrease in sparse vegetation and agricultural land.

Table 20.1 Percentage change in land use of NCT Delhi (1977–2014) (Dutta and Rahman 2017)

LULC classes	Area in percentage (NCT Delhi)			Change (%)	
	1977	2003	2014	1977–2003	2003–2014
High-density built-up	1.62	8.79	28.42	7.16	19.63
Low-density built-up	11.03	25.52	19.01	14.5	−6.51
Dense vegetation	7.61	8.91	10.62	1.31	1.7
Agricultural land	38.23	31.42	26.96	−6.81	−4.46
Sparse vegetation	29.01	16.81	8.41	−12.2	−8.4
Water body	1.98	1.54	1.47	−0.44	−0.07
Wasteland	10.52	7	5.11	−3.52	−1.89
Total	100	100	100		

This study shows that the expansion of built-up areas in NCT Delhi was only about 12.65% of the total area in 1977. The built-up area expanded to approximately 50% of the total area of NCT Delhi by 2014. This expansion was recorded for a period of 37 years. In another study of NCT Delhi, the spatio-temporal transformations were recorded by (Sirkarwar and Chattopadhyay 2015) using the land use and land cover analysis technique for the past three decades following the census years. Delhi was compared with other metropolitan areas of India such as Mumbai, Chennai, Bengaluru, Kolkata and Hyderabad. It was observed that the built-up area in NCT Delhi was 27% in 1991, 42% in 2001 and approximately 65% in 2011. It corroborates with the other study confirming the rapid pace of urbanisation in NCT Delhi. In comparing Toronto with NCT Delhi, it can be observed that the rate of urban expansion in NCT Delhi from 1977–2014 was much more than in Toronto in the period 1974–2014. Since the city of Toronto was already urbanised in 1974, a significant expansion is observed in the case of NCT Delhi.

Study Areas

The research investigates two study areas, each selected from the global north and the global south. The two cities selected for the case study are Toronto and NCT Delhi. The two cities are selected to assess and compare the spatio-temporal transformations and land use changes and their subsequent impacts on the water security of cities and also, to observe the current water conservation practices implemented in the cities by the respective authorities.

Toronto, Canada

Toronto is the most populous city in Canada and the provincial capital of Ontario. It caters to a population of 2,731,571 (Toronto Census 2016). Toronto covers an area of 630.2 km^2. Its borders are formed by Lake Ontario in the South, Steeles Avenue in

Fig. 20.2 Regions of the Greater Toronto Area (University of Toronto 2018)

the North, Scarborough in the east, and the western boundary of Marie Curtis Park. Figure 20.2 shows the nearby regions of Toronto, including the regions of York, Durham, Peel, Halton and the city of Hamilton.

The growth in the GTA is influenced by the growth of Toronto city as it acts as the centre of development of the urban region. The Toronto area comprises 45% of the total population of the GTA (Census Backgrounder Report—2016). This study mainly focuses on understanding the impact of land use dynamics on the water consumption patterns of the city of Toronto. The density of Toronto is 4150 persons per km^2. Which is the largest compared to the rest of the regions of GTA (Table 20.2). Toronto is the most populous city in the GTA, catering to 630 km^2. Toronto has undergone a series of administrative or spatial changes over the past few decades. In 1998, the six lower-tier municipalities York, East York, North York, Etobicoke, Scarborough, and Toronto, amalgamated into the city of Toronto, thus expanding it greatly.

NCT Delhi, India

Delhi, or the National Capital Territory of Delhi (NCT Delhi), is bordered by two states, Haryana on three sides and Uttar Pradesh on the east. NCT Delhi covers an area of 1484 km^2. The city of Delhi caters to a population of eleven million, while NCT Delhi caters to 16.8 million (Census of India 2011). NCT Delhi has five municipal corporations, which are New Delhi Municipal Council (NDMC), East Delhi Municipal Corporation (EDMC), North Delhi Municipal Corporation (NDMC), South Delhi Municipal Corporation (SDMC), and Delhi Cantonment. The SDMC is spread across Southern and Western Delhi comprising Janakpuri, Dwarka, Tilak Nagar, Sadar Bazaar, Chandni Chowk, etc. (Fig. 20.3).

Table 20.2 Comparison of regions of the Greater Toronto Area (Toronto Census 2016)

	Total area (km^2)	Population	Density (persons per km^2)
Durham	2523.15	645,862	241
York	1761.84	1,109,909	586
Peel	1241.99	1,381,739	1040
Halton	967.17	548,435	520
City of Toronto	630	2,731,571	4150
Greater Toronto Area	7124.15	6,417,516	850

Fig. 20.3 Map of NCT Delhi (right) and its location in India (right)

Demographic Profile—A Comparison

Toronto, Canada

Toronto is the most populous city in the country and serves as the centre of the economy for the country. Delhi has been one of the fastest-growing cities in India. A large portion of this population increase has been due to continuous migration. NCT Delhi also attracts the population from nearby cities such as Ghaziabad, Noida, Greater Noida and Gurgaon.

The population of Toronto grew by 3.8% during 1991–1996, 4.8% during 1996–2001, 4% during 2001–2006, 1% during 2006–2011 and 4.5% during 2011–2016 (Fig. 20.4) (Statistics Canada 2016).

While reviewing the population growth rate of Toronto during 2001–2011, an abrupt decrease is observed in the year 2006. Toronto records only a 0.9% population

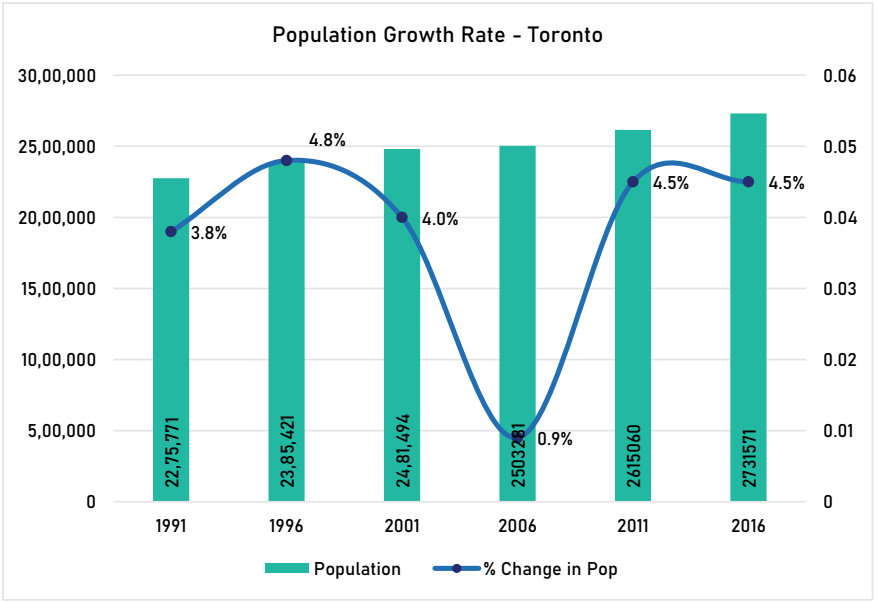


Fig. 20.4 Population growth rate of Toronto over the last two decades. *Source* Census of Population 2016, Statistics Canada

growth rate from 2001 to 2006. This unusual decline in the percentage change in the population reflects the likelihood of the Census missing more people for records than it usually does. The statistical data shows a difference of 61,270 units (5.9% of the total units) between the total dwelling count and the personal dwellings occupied by the residents. The 2001 census report shows only 22,475 such units (2.3% of the total (Toronto Census 2006)).

The choropleth mapping of population density persons per hectare (pph) of Toronto for the years 2011 and 2016 shows the concentration of population and the manner of population densification at particular regions over the years (Fig. 20.5).

In 2011, 60 pph or more population density was observed in Wards 14, 17, 18, 19, 20, 21, 22 and 27, comprising Parkdale, Davenport and Main Toronto Centre. In 2016, population density increased from approximately 55–70 pp ha. in wards 23, 26, 31 and 32, comprising Willowdale, East York and Parkwoods. The areas with the largest population percentage changes, i.e. more than 50% increase, are located in Toronto Waterfront, Mimico area, and King West.

NCT Delhi, India

In the case of NCT Delhi, the aggregate population growth rate for the decade 2001–2011 is 21.21%. The population growth in NCT Delhi is recorded much more than in Toronto during the same period. Table 20.3 shows the summary of the demographic profile of each district of NCT Delhi.

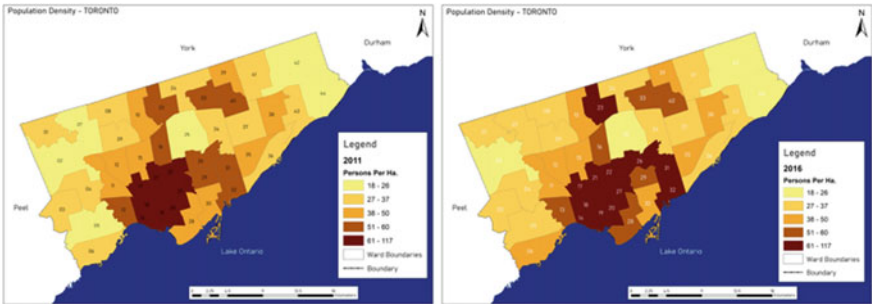


Fig. 20.5 Choropleth map representing population density—Toronto 2011 (left) and 2016 (right). *Source* Authors

Table 20.3 Demographic details of NCT Delhi—District-wise (Census of India 2011; Biswas and Gangwar 2020)

District	Area (in km^2)	Population	Population growth rate 2011	Population growth rate 2001	Density (p.p. km^2)	No. of households
North-West	443	3,656,539	27.81	60.91	8254	732,966
South	247	2,731,929	20.51	50.95	11,060	568,863
West	130	2,543,243	19.46	48.56	19,563	530,467
North-East	62	2,241,624	26.78	62.92	36,155	404,676
South-West	421	2,292,958	30.65	61.37	5446	491,521
East	63	1,709,346	16.79	43.06	27,132	357,173
North	61	887,978	13.62	13.82	14,557	174,779
Central	21	582,320	−9.91	−1.55	27,730	115,090
New Delhi	35	142,004	−20.72	6.19	4057	32,051
Delhi State	1483	16,787,941	21.21		11,320	3,407,586

East, north-east, central, and western districts of NCT Delhi cater to a larger population than other parts of the city. The first map is the dot-density map which helps to understand the relationship between the number of persons residing in the area and the spatial area of that district. The second map is the choropleth map of population density which shows that the north-eastern district is the most densified compared to other districts in terms of population density. The third is a bivariate map showing the decadal population growth rate for two decades, i.e. 1991–2001 and 2001–2011 (Fig. 20.6). The south-western district has witnessed the highest population growth. Central Delhi and New Delhi witnessed a declining population growth during 2001–2011. The north-western district has the largest number of households, while the south, west and south-western districts have more than 500,000 households in each (Biswas and Gangwar 2020).

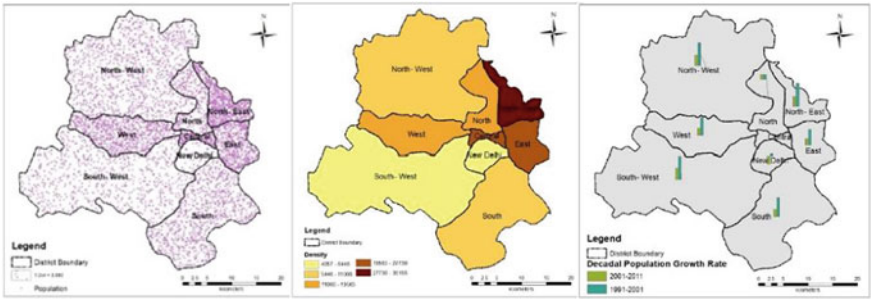


Fig. 20.6 Population distribution, population density and population growth maps of NCT Delhi's districts (Biswas and Gangwar 2020)

Thus, the demography of NCT Delhi shows that the western district has more potential for growth in the future as the eastern district has reached its saturation in terms of accommodating population.

Spatio-Temporal Changes—A Comparison

The land use and land cover change technique is used to analyse the spatio-temporal growth of the city of Toronto. The supervised classification in ArcGIS software from the Landsat 4–5 and Landsat 8 imageries for the years 1996, 2006 and 2016 is used for the change detection analysis. The imageries obtained have a spatial resolution of 30 m. The Landsat imageries are retrieved from the United States Geological Survey website. These specific years were selected to correlate with census data availability and the needs of the research. Land use is classified into five categories: built-up area, roads, vacant land, vegetation and water. The limitation of the land use and land cover analysis is that the Landsat imagery received for the year 1996 is not clear and may affect the outcome. The methodology followed to calculate land use land cover change analysis is given in Fig. 20.7.

The change in built-up areas for two decades can be visually observed in Fig. 20.8. It shows the concentration of built-up in Etobicoke, York University Heights, Old Toronto, and the downtown area of Toronto, etc. The remote sensing imagery analysis of 1996 may not be accurate due to the poor quality of imagery retrieved.

Toronto, Canada

Comparing the land use land and cover change (LULC) of 2006 and 1996, it is observed that the built-up area concentrated more on the eastern side, i.e. Scarborough, North York, parts of Etobicoke and Malvern. Further comparing the LULC imagery of 2016 and 2006, expansion of city centres such as Midtown Toronto and New Toronto area was observed. The analysis also reveals built-up area densification in downtown, Newtonbrook along Yonge Street, Etobicoke and North York.

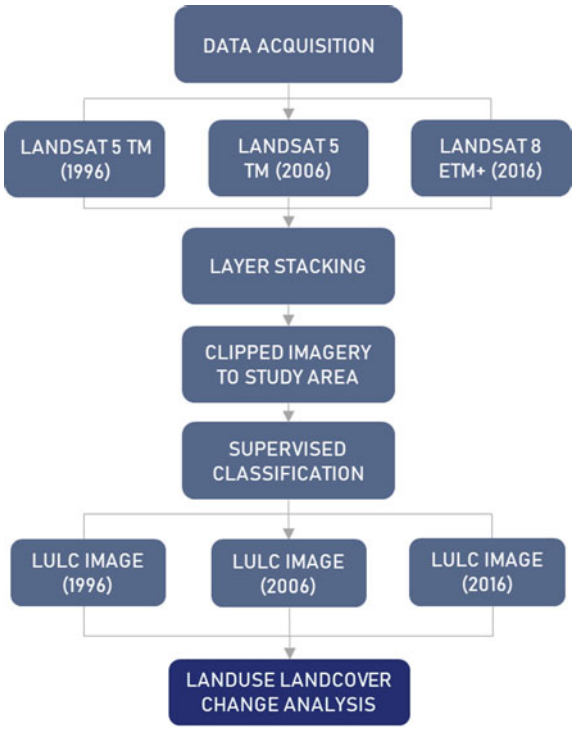
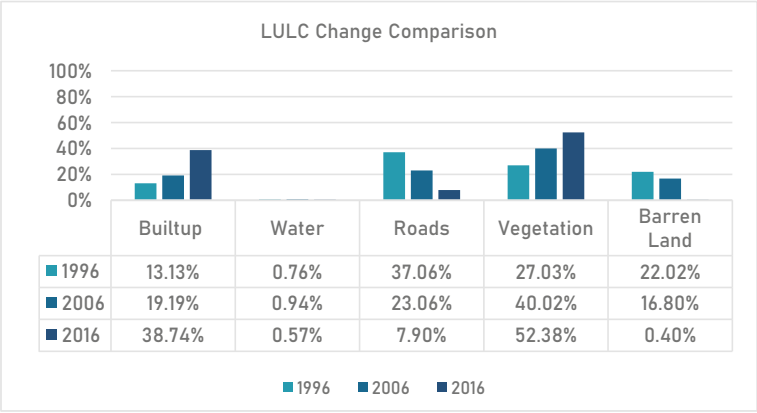


Fig. 20.7 Methodology for land use and land cover change analysis process



	Builtup	Water	Roads	Vegetation	Barren Land
1996	13.13%	0.76%	37.06%	27.03%	22.02%
2006	19.19%	0.94%	23.06%	40.02%	16.80%
2016	38.74%	0.57%	7.90%	52.38%	0.40%

Fig. 20.8 Land use and land cover change comparison (1996–2016)

The quantum of change in land use for the two decades, i.e. 1996–2006, and then 2006–2016 can be compared in Fig. 20.8. It can be inferred that the built-up area has increased from 13.13 to 19.19% in 2006, i.e. an increase of approximately 6%. From 2006 to 2016, the percentage of the built-up area almost doubled from 19.19% in 2006 to 38.74% in 2016. The percentage of surface water is only 1% of the total land cover. The decline in roads is particularly observed in 2016. The satellite imagery detects the presence of trees along the roads which covers a large portion of road areas. Since 1996 vegetation has increased at approximately 12% per decade until 2016. In the case of barren land, there was a sudden decrease in percentage between 2006 and 2016 due to a sudden increase in the built-up area.

NCT Delhi, India

In the study by (Biswas and Gangwar 2020), the land use and land cover change analysis is calculated using the thematic services of Bhuvan, the Indian Geo-Platform of the Indian Space Research Organisation (ISRO). This thematic service is used to acquire land use and land cover maps of NCT Delhi for 2006, 2012, and 2018. The collected maps are overlaid to study the change in various land cover categories. The limitation of the study is the very large-scale maps retrieved as the study area and the difficulties in calculating the approximate change in the built-up area at the city scale. Therefore, a macro-level study was performed for more accurate information. The city is divided into 14 × 14 km grids. The overlaid layers are analysed for each grid, and the approximate percentage change is recorded.

Built-up areas in the south-west, north-west and western districts have increased 5–20% from 2006 to 2018. The 'urban growth monitoring system' of NCT Delhi helped detect the direction of growth in the western districts. One of the reasons for such transformation is the large portion of urbanisable area demarcated in the Master Plan of Delhi 2021.

Water Management in Toronto

In Toronto, the 'Toronto Water Division' is a municipal division under 'Infrastructure and Development Services' that is accountable for managing and monitoring the water supply network. All the facilities related to water supply and its network, such as treatment plants, pumping stations, water mains, are managed by the Toronto Water Division. The water supply system and the treatment facility consist of eighteen pumping stations, four elevated storage tanks, eleven underground reservoirs, four treatment plants and more than 6000 km of water distribution pipeline network (Toronto Water Division 2020). The major water source for the city of Toronto is the Ontario Lake adjacent to the downtown area. The daily water demand in Toronto rises in July, the warmest month of the year.

The behavioural analysis and per capita water consumption patterns are done by analysing the choropleth maps for each ward. The darker colour indicates more consumption. The mapping is done for two periods, i.e. 2006 and 2015. The data for

2016 was unavailable to carry out the analysis. The closest spatial data to the census year is available for the year 2015, which is considered for the research. The analysis will help assess the water security of a decade in terms of total water consumption and per capita water consumption.

Figure 20.9 shows the map of total water consumption of Toronto city in million litres per day (MLD) for the years 2006 and 2015. In 2006, wards 2, 5, 6, 20, 27, 28 and 37 had the highest cumulative water consumption of 11 MLD or more. These areas include parts of Etobicoke, Trinity and Toronto's downtown area. The least total water consumption, i.e. below 4.5 MLD, was observed in wards 13, 17, 18, 29 and 32, covering areas of Parkdale, Davenpor, etc. Between 2006 and 2015, the total water consumption decreased in wards 5, 9 and 6, which are the areas of Etobicoke, and York Centre areas, by approximately 1.45 MLD. In ward number 32, i.e. the East York area, the total water consumption increased by 1.5 MLD. The mapping was done for 2006 and 2015 to study per capita water consumption. The per capita consumption is mapped in litres per capita per day (LPCD). The highest per capita water consumption of 160 L or more is observed in wards 2, 5, 6, 7, 8, 11, 20, 27 and 28, which majorly include large parts of Etobicoke and the downtown area of Toronto (Fig. 20.10).

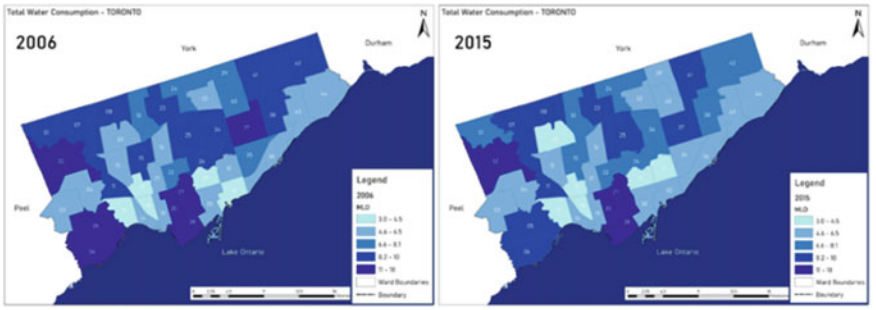


Fig. 20.9 Total water consumption for the year 2006 (left) and 2015 (right) in Toronto

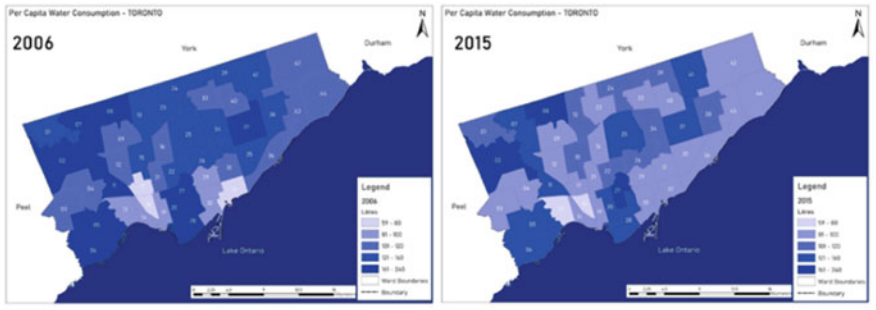


Fig. 20.10 Per capita water consumption for the year 2006 (left) and 2015 (right) in Toronto

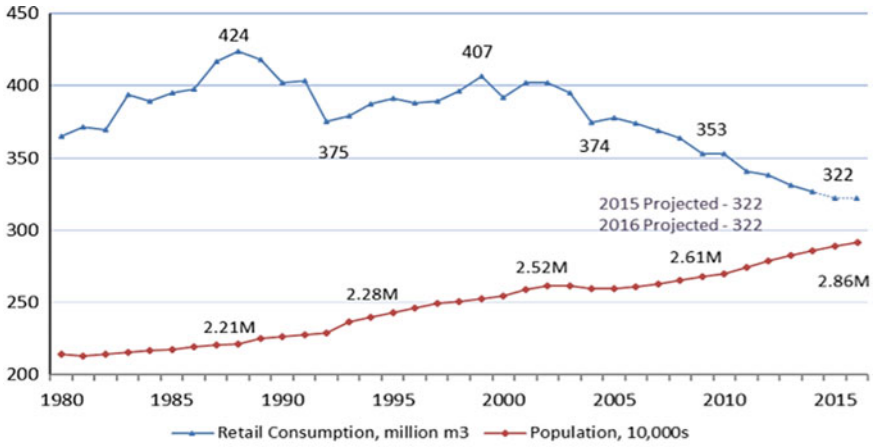


Fig. 20.11 Toronto water consumption comparison with population growth (1980–2015) (Toronto Water Division 2016)

Per capita, water consumption declined by approximately 20 LPCD in Eastern and South-Eastern Toronto between 2005 and 2016. A declining trend is observed for both total and per capita water consumption.

Figure 20.11 compares the water consumption and population of Toronto over 35 years, showing a similar trend of declining water consumption from 2005 to 2015. It can be seen that the population over the years has increased at a significant rate, but water consumption has decreased. The water consumption in 2005 was recorded to be 374 million m^3, and the population was approximately 2.52 million. In 2015, the population expanded to 2.86 million at the rate of 4.5%. However, the water consumption recorded was only 322 million m^3. The weather conditions influenced this decline in water consumption. This decline is justified by water efficiency measures and other significant economic factors (Toronto Water Division 2016).

Bennett (2013) studies the correlation between the decline in water demand and water pricing. From 2005 to 2011, it was observed that a 6% decline in the water main breaks would only contribute 0.06% to the decline in water consumption. Therefore, water main breaks are not a significant factor in decreasing water consumption patterns. The decline in water consumption patterns was assessed through the changes in water pricing. Toronto city implemented an aggressive water pricing strategy for the conservation of water. Water pricing has been revised every year since 2003, with an increment ranging from 6 to 10.8% (Bennett 2013). Toronto witnessed a 24% decline in per capita water consumption due to the rising water price. Before 2008, water pricing was based on a seven-step block rate structure. In 2008, this approach was revised and a general rate for all of the water consumed was adopted for the citizens consuming less than or equal to 6000 m^3. The water pricing increased from CAD 1.35/m^3 in 2005 to CAD 2.28/m^3 in 2011 for residents of the city (1 CAD = 0.75 USD) (Bennett 2013). There are some strategies devised for the conservation of water by the Toronto Water

Division. One of the strategies is the industrial water rate program, which offers discounted water to manufacturers to help sustain economic growth and encourage water conservation. Manufacturers consume more than 5000 m^3 of water annually which belongs to the industrial property tax class (Toronto Water Division 2020).

Water Management in NCT Delhi

Groundwater is widely consumed to meet the growing industrial, agricultural, and domestic water demand in rapidly urbanising Delhi. The aggregate water requirement for domestic and drinking purposes is approximately 913 million gallon per day (MGD). 845 MGD (out of 913 MGD), including approximately 100 MGD from groundwater, is contributed by Delhi Jal Board (DJB). The DJB is responsible for distributing potable water after treating raw water and wastewater disposal. The present deficit in the drinking water supply is about 112 MGD (Biswas and Gangwar 2020).

Approximately, 83% of households have access to the piped water supply. During the summer, water production is consistently maintained at 896 million litres per day (MLD). The largest water supply sources in NCT Delhi are Ganga and Yamuna rivers, followed by Bhakra storage and other groundwater sources. NCT Delhi depends on the neighbouring states to meet almost half of its total drinking water demand. The DJB is continuously working on improving the water supply and the treatment facility in every five-year plan (Planning Department, Delhi 2018). The existing water supply network in NCT Delhi comprises a 14,355 km long water supply pipeline and more than 107 groundwater reservoirs. Besides the conventional water supply network system, NCT Delhi also focuses on other methods to improve access to the water supply. These include adding 407 new water tankers equipped with GPS; 400 M.S hired tankers; 250 newly purchased stainless steel tankers to supply water in the deficit areas. The total metered water supply connections aggregated to approximately 2,082,967 in 2017–2018 (Planning Department, Delhi 2018). At least half of the drinking water demand is met by tap water from a treated source in all the districts. The south-west, west and southern districts fulfil a substantial portion of drinking water demand by tube wells/boreholes (Table 20.4).

The service-level benchmark has set nine indicators and the benchmarking values to measure the current status of water supply in an area. The comparison of the prescribed service-level benchmark suggested by the Ministry of Housing and Urban Affairs (MoHUA) and the present values of NCT Delhi is presented in Table. It is observed that the coverage in NCT Delhi is not adequate and only adds up to 71.5% of the total required connections. However, the per capita water supply provision of 145 LPCD is greater than the suggested value. Other parameters such as the extent of non-revenue water, metering, efficiency in the redressal of customer complaints, collection of water charges and quality of water supplied indicated that the present situation in NCT Delhi is surpassing the benchmarking values of these parameters. However, the continuity of water supplied is only 3 h as opposed to the suggested

Table 20.4 Service-level benchmarking for water supply (MoHUD 2019)

S. No	Indicator	Benchmark	NCT Delhi
1	Coverage of water supply connections	100%	71.5%
2	Water supply per capita	135 lpcd	144 lpcd
3	Extent of non-revenue water	20%	11%
4	Extent of metering	100%	55.3%
5	Continuity of water supplied	24 h	3 h
6	Efficiency in redressal of customer complaints	80%	58%
7	Water quality	100%	99.5%
8	Cost recovery	100%	41.6%
9	Efficiency of water charges collection	90%	78%

duration of 24 h which is very low. Further, the cost recovery of existing water supply management is only limited to a mere 41.6% which should be 100%.

For further assessment, the city can be subdivided into specific hydrogeological units: (a) Older Alluvium—Isolated; (b) Older Alluvium—Eastern and western sides of the ridge; (c) Newer Alluvium—Yamuna flood plain deposits and nearly closed Chhatarpur alluvial basin and (d) Quarzitic Formation—NNE-SSW trending Quarzitic Ridge (Central Ground Water Board 2016). West, south and south-west districts are the areas with the highest potential groundwater reserve. This continuously increasing population of NCT Delhi affects the availability of groundwater. The rate of consumption of groundwater is much more than that of replenishment. The Central Groundwater Board (CGWB) recorded that the net groundwater availability in NCT Delhi is 28,156 ha m (hectare-metre) and the annual replenishment is 29,710 ha m Purohit et al. (2009) observed that the annual groundwater draft for NCT Delhi (as in 2004) was 47,945 ha m of which 21,506 ha m is used for domestic purposes, 20,002 ha m for irrigation purposes, and 4300 ha m for industrial purposes (Purohit et al. 2009). Rainwater harvesting is considered a major mean of groundwater recharge. NCT Delhi is mostly urbanised, i.e. having a high density of the built-up area comprising 142 km^2 roof area, 69 km^2 paved area and the remaining 485 km^2 open area/green area (Central Ground Water Board 2016). It results in a large volume of surface runoff due that diminishes the possibilities of rainwater harvesting as a solution to recharge groundwater.

The central government's Yamuna Action Plan (YAP) initiative attracts attention to the conservation of water resources in NCT Delhi. Under this plan, eleven projects have been identified to conserve the river Yamuna as a water resource. In phase three of YAP, nine projects for the rejuvenation of Yamuna were identified, of which eight focused on sewerage infrastructure (Greens 2019). Approximately, 40% of the treated water is lost due to misuse, leakage in pipelines and un-metered connection. Therefore, water conservation and leak detection are vital for water security in NCT Delhi. The government started to incentivise free water consumption up

to 20 kilolitres (kl) per month to avoid misuse of water. Any consumption outside this 20 kl is chargeable.

Discussion and Conclusion

The study of Toronto and NCT Delhi shows that the cities underwent dynamic changes in expanding population and the built-up area. Since the late twentieth century, both cities have experienced rapid urbanisation with the largest percentage of increase in the highly dense built-up class. For Toronto, the built-up expansion took place from downtown Toronto radially. Also, the high-density built-up area sited along Lake Ontario in a ribbon pattern which influenced the growth of the rest of Toronto. In the case of NCT Delhi, the growth of the built-up area was mainly concentrated in the central and eastern regions in the late twentieth century. However, in the past three decades, the built-up expansion densified in the central and eastern regions, and new development took place in the south, west and south-western regions. In comparing the growth of NCT Delhi to the proposed master plan of 2021, the growth of Western Delhi is influenced by the area demarcated as an urbanisable area in the master plan for future expansion. The urban expansion experienced by both Toronto and NCT Delhi puts immense pressure on infrastructure facilities, specifically on water resources.

The Toronto Water Division manages and regulates water across the city. Water consumption has increased in parallel with urban expansion till the 2000s. Water consumption was significantly high in the year 2000. This increased water consumption was rationalised through strategies like water pricing. During 2005–2015, a decline in water consumption was observed amidst a significant increase in population. This decline in water consumption was attributed to the revised water price rates introduced in 2008. The increment in water price was approximately Canadian Dollars (CAD) one/per cubic metre from 2005–2011. The increment in pricing was the strategy followed by the Toronto Water Division's aim to conserve water resources and achieve water security by restricting the citizens from wasting water.

In NCT Delhi, the comparison of the existing facilities through the service-level benchmarking shows a significant shortage in water supply coverage and its continuity provision. Many conservation strategies were devised for NCT Delhi, including water metering strategies. This strategy includes providing piped water supply free of cost up to a consumption of 20 kl/month. An increased tariff is charged to encourage citizens to conserve water beyond this stipulated consumption volume. The deteriorating groundwater table of NCT Delhi is specifically observed at the beginning of the summer season. This is particularly pragmatic in the south and south-western districts. If the piped water network does not penetrate further within the growing settlements, a further increase in groundwater extraction becomes unavoidable. The groundwater depletion will further accelerate due to increased extraction and decreasing groundwater discharge.

In Toronto, aggressive water pricing is implemented to reduce excess water consumption. The revision of water pricing introduced in 2008 significantly impacted water conservation and management. NCT Delhi's water management authority followed a different approach, including a flexible water metering strategy. This strategy includes a free water supply of a fixed amount and a higher water tariff beyond the free cut-off volume. This model ensures that citizens do not waste water beyond the required consumption. These two cities from the global north and global south used different strategies to mitigate the growing gap between demand and supply and attain water security. The difference in economic and development scale between the two cities results in different approaches to water security and overall urban water management. This may create an equitable gap in the accessibility of water facilities in the communities. Toronto may adopt a similar water metering strategy like NCT Delhi to reduce the hardship of paying high water tariffs by students, urban poor, and low-income people.

This research will facilitate policy makers for detailed comparative understanding of land use transformation and water security between global north and global south. The future researches may further explore comparative researches on the conflict between water consumption pattern and built form intensification between global north and global south with high resolution imageries to achieve more accuracy and enabling on-ground strategic interventions by the policymakers.

Acknowledgements We would like to thank the Shastri Indo-Canadian Institute for their financial support under the Shastri Indo-Canadian Research Grant (SICRG) 2018. We would also thank the Indian Institute of Technology (IIT) Roorkee and the University of Waterloo for facilitating this collaborative research.

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