Group #10 Project

GGR335H5 - Winter 2022

Urban Sprawl In the Halton Region

How is Urban sprawl impacting Halton Region's Population and Landscape?

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Introduction:

Will Ontario's Halton Region farmland ever stop being developed on? In recent years, Halton Region has become a powerhouse to urban development with huge increases in population and immigration rates. The development has ramped up so much in Halton Region that just recently 5000 acres of development land is being proposed to open for development (McIntosh, 2022). With Halton Region's increased development and urban sprawl there has already been land reserved in place for development up to 2041 but it is not enough (McIntosh, 2022). The region of Halton had an increase of 14% in its annual GDP, which from an economic perspective points to a major driver of urban expansion (Qing et. al., 2020). The evolution of cities, combined with their diverse set of pressures caused by speculated growth, put forth significant obstacles against the ability to maintain order in the built environment (Murray, 2021). Urban sprawl in Halton region is increasing at such a fast rate that there are movements going on demanding the stop of the urban sprawl occurring in Halton Region.

One of the prominent movements that is spurring up is called the "Stop Sprawl Movement". The Stop Sprawl Movement has many goals, for starters the movement wants to save the 5000 acres of prime agricultural land that is going to be developed on (Stopsprawlhalton, n.d.). The movement argues that "Low density does not pay for itself and results in a deficit, whereas higher density actually saves money." (Stopsprawlhalton, n.d.). The movement says that halton has already declared a climate emergency in all four of its municipalities and designation 5000 acres of land is not what the halton region should be doing (Stopsprawlhalton, n.d.). The movement also goes as far as submitting a recommendation report to the city's growth strategy. The city's growth strategy is known as ROPA 49 (Regional Official Plan Amendment 49) and defines how and where Halton region will grow. The movement aims to submit a ROPA 49 recommendation report in hopes of limiting urban sprawl. It is evident that urban sprawl is prominent in the Halton Region and its effects on the region need to be understood and looked at.

Halton region's population is growing year on year coinciding with urban sprawl. Urban sprawl has a lot of negative effects on the environment for example some negative impacts include but are not limited to are loss of environmentally fragile lands, greater air pollution, higher energy consumption, loss of farmland, reduced diversity of species, increased runoff of stormwater, and increased risk of flooding (Johnson, 2001). So as seen this is why looking at the rate of urban sprawl is very important as if growth is uncapped there will be severe environmental consequences in the future. There are many ways urban sprawl can be limited and if needed urban growth boundaries, new greenbelts and high density growth can be put in place to slow down the growth (Johnson, 2001).

Some of the main reasons urban sprawl is caused is economic growth for example increase in income per capita, increased number of workers leading to more demand for housing and urban growth and industrialization increasing at city boundaries increases demands for houses at the edges of cities (Karakayaci, 2016). Therefore, with the rapid expansion of the Halton Region, our research focuses on how the rate of urban sprawl growth has impacted and influenced the population and its landscape within recent years. Our objective is to use Landsat images and remote sensing to analyze the rates of urban sprawl growth as its patterns will help determine how Halton's agricultural and economic development sectors will be in the future. By determining this perhaps some measure can be put in place to stop the urban sprawl in Halton region to reduce its negative effects as urban sprawl is not something that should be left to spread without limitations.

Methodology:

It is clear that after our research objective, as outlined in the conclusion of the introduction, our main focus will be to analyze the urban landcover within the Halton boundary (Figure 1). This region, mainly comprising the City of Burlington, Halton Hills and the towns including Milton and Oakville is situated in Canada precise on the coordinates 43.53°N, 79.87W. The Halton Region presents one of the key regions of transition in which the Carolinian life zone converges with the large Great Lakes-St Lawrence Forest area, the expansive Niagara Escarpment as well as the shoreline of Lake Ontario. The natural environment of the Halton Region presents intricate biological and physical features. Among such include an avalanche of microclimates attributed to changes in the elevation, soils and weather patterns of the Great Lakes. Each of the physical features is supportive of the wild animal species and habitats from the endangered cliff-top communities besides the northern conifer exhibiting deciduous swamp forests.

We will be using 5 Landsat images, about 5 years apart between 2001 to 2011 and 4 years apart between 2017 and 2021, within Ontario's Regional Municipality of Halton. These images will be utilized in analyzing the changes in the land cover attributed to urban sprawl. Built-in base map layers in ArcGIS will also be used in the initial stages of atmospheric correction and rectification of the image. The next stage will involve the classification of the images based on the land cover type with the aid of a supervised classification method. This was informed as this study aimed to evaluate urban built-up areas alongside and from the urban sprawl-initiated changes. A change detection analysis will then be performed for observation of the different land cover type's changes across the various periods. This will be done with a specific focus on the classes of vegetation and urban cover for analysis of urban sprawl. A Normalized Difference Vegetation Index(NDVI) and Normalized Difference Built-up Index(NDBI) analysis will further be conducted on the two Landsat images for refined classification of vegetation and built-up areas, and thereafter making a comparison of the variations in such indices over the period.

The census and region of land cover types filtered by total area by population density will then be used in conducting statistical analysis of the Halton Municipality throughout the Landsat images, for determination of the sprawl indexes and growth rates. Halton Region's Municipality division level census data was also incorporated in this study for use in the evaluation of the effects of population growth on the rates of urban sprawls. QuickBird images extracted in 2004 were used in the rectification of the five images after which the Landsat images were grouped into one of the three categories including vegetation, urban and residential.

Change detection matrix was achieved using the matrix union tool which was used on every pair of consecutive images. The colour scheme (Table 1), was used in renaming the classes with the most important one being the changes to urban residential from vegetation being illustrated in red. The normalized built index was as well integrated into this analysis for emphasis on the built-up areas with a specific focus on the changes noted in the built-up spaces or progress noted in the last two decades in the area.

Results:

As discussed earlier, our research project's methodology was to analyze the urban landcover within the Halton boundary (Figure 1), across five census years. This was done so by measuring the NDVI and NDVI indexes, supervised land cover classification, and a land cover change detection analysis. In addition, we had analyzed changes in the Ontario Greenbelt boundary, due to concerns of development and urban sprawl encroaching into these protected lands (McIntosh, 2022).

Through the NDBI and NDVI analyses, we produced a table (Table 2) to compare the Population, Population Density, Total Land Area, Total Built Area, and Urban Build-up Rate across the different census year images. When observing all five years from 2001 through to 2021, we observed that the Halton Region's population and population density have increased significantly (375,229 in 2001 to 596,637 in 2021), and so has the Urban Build-up Rate (7.86% in 2001 to 20.94% in 2021).

As mentioned in our methodology, we had also performed a supervised land cover classification on the five census year Landsat images (Figure 4). Quick Bird images extracted in 2004 were used in the rectification of the five images after which the Landsat images were classified into one of the three categories including vegetation, urban and residential. With any classification, it is important to do an accuracy assessment. An accuracy assessment compares classified images with a ground-truth/accurate reference image, to determine how well the classification reflects the actual land surface. The accuracy assessment was conducted using 20 stratified random sample points, and the result is summarized in Table 3. The classification scheme has an overall accuracy of 75 percent, and a kappa statistic of 61.69 percent. While overall accuracy is a straightforward statistic, the kappa statistic is a measure of the proportional (or percentage) improvement by the classifier (supervised classification) over a purely random assignment of the classes.

The change detection analysis (Figure 5), barring some error in the classification of urban landcover, shows change detection across the three classes, with urbanization patterns highlighted in red. With regards to concerns with the Ontario Greenbelt, it is important to indicate that this region (Figure 6) is a large boundary, which provides water, food, and clean air for the human population. In addition, the Ontario Greenbelt helps to protect farmland and affects as a Carbon sink (Greenbelt Plan, 2017). As the Ontario Greenbelt came into effect in 2005, we choose to conduct our analysis starting from the year 2006. The analysis was conducted by generating maps of the Ontario Greenbelt over the years 2006, 2017 and 2021 (Figure 7). In Figure 7, we produced a graph of Urban Usage in Ontario's Greenbelt from the years 2006 to 2021.

Discussion:

As discussed in the results of the analysis, there were visible changes that were evident following the processing of the 5 Landsat images, and then their resulting maps which were constructed with the use of additional layers (including the shapefiles that provide the Halton regional municipality boundary (Land Information Ontario, 2012) and Greenbelt boundary ("Greenbelt Plan mapping", 2017). The information available in these maps is best interpreted when each consecutive map is observed in chronological sequence, due to the foundation of the analysis in this report which consists of a sequence of 5 points in time at which satellite imagery was captured.

One important aspect which is necessary to consider (before interpreting the results) is the fact that images 1, 2 and 3 were captured via the Landsat 5 sensor, while images 4 and 5 were captured via the Landsat 8 sensor. In terms of the capabilities of each of these sensors, it should be noted that in general, landcover maps that are produced using Landsat 5 imagery are less accurate in comparison to landcover maps that are produced using Landsat 8 imagery (Poursanidis et. al., 2015). This has been demonstrated in prior research in which imagery from each of the two sensors was used in conjunction with pixel-based analysis in order to classify and map urban landcover types (Poursanidis et. al., 2015), which is a similar application as the methodology which is used in this project and earlier explained in this report.

With this consideration in mind (of the difference in accuracy that arises from the use of both Landsat 5 and Landsat 8 imagery), it should be noted that the images taken in 2017 and 2021 (image 4 and image 5 respectively) may have produced more accurate classified maps and NDBI maps in comparison to the maps produced from the images taken in 2001, 2006, and 2011 (images 1, 2 and 3 respectively). However, one must also consider the fact that better accuracy might not necessarily imply better results in each of these maps, as the ability to accurately achieve the methodology of this project was also affected (and likely limited) by the human factor which is present in how the supervised classifications were performed by multiple group members with naturally different visual perceptions of landcover types, resulting in a possible human error caused by different habits in creating signatures of supervised classification. This error is also possibly accompanied with another error caused by the overall use of supervised classification as well, with consideration to the fact that human input of polygons representing different landcover types may also create additional errors as discussed earlier in the course.

One of the main aspects of the results in our analysis is the NDBI maps which indicate a gradual and progressively increasing presence of ‘urban’ landcover. A main element of inaccuracy in these maps is evident in comparing the results of these maps to the original Landsat imagery, or more conveniently, with a recent (within 1-2 years) satellite image of the Halton Regional Municipality, as demonstrated in Figure 2 and Figure 3 in the appendix.

It is apparent that the NDBI methodology resulted in many agricultural areas being included in the output of the NDBI calculation. However, at the bottom of Figure 2 in the appendix (showing the NDBI areas highlighted in light-blue), the visible belt-like shape consisting of urban areas in Oakville and Burlington demonstrate the extent of urbanization with some degree of accuracy, when compared with the urban areas in these locations that were shown in the NDBI outputs generated from the other Landsat images. Therefore, in specific areas of the Halton region, the NDBI analysis was accurate and indeed demonstrated urban growth. However, although the extent and speed of this urban growth was determined using the NDBI calculations on each original Landsat image, the overall amount of urbanization must be established in the context of the supervised image analyses, as well as the sociological data represented by the census data which is a part of the research in this report.

The supervised classification appears to indicate vast changes across the entire Halton region (represented in red on the supervised classification map in the previous section). However, this is likely due to error resulting from the process of creating the signature of the supervised classification, as additional examination with the use of the Landsat image (configured in True Color Composite) revealed that the urban areas (namely, the built environment) did not expand in the scattered manner deep into vegetation (primarily agricultural) landcover.

Table 1 in the appendix (shown in the first image of the Results section) allows for the comparison of the census data with the data produced from the remote sensing analysis. Although the total population of the region and the total built area both demonstrate significant increases, a very important part of the table is also shown in the population density column. As the population density is shown to have increased dramatically, there has therefore likely been a significant increase in the density of residential areas within the region, and this trend may perhaps counteract the trend of urban expansion - due to the possibility that the demand for lower-density housing may be affected by different factors than the demand for higher-density housing.

This possible variety in the housing needs of the residents of Halton may result in future changes to the rate of urbanization, and the extent to which the rate of urbanization is not consistent over the past 20 years (2001-2021) has been a major finding in this report, especially considering the earlier notions observed in the literature which generally suggested that the region is growing at an alarming rate, but did not quite specify how and at what consistency (as overviewed in the introduction section)

Conclusion:

In conclusion, urban sprawl is prominent in the Halton Region and is expected to continue to grow if no sprawl mitigation measures are taken. It is evident that one of the greatest factors leading to urban sprawl in the Halton region is due to the rapid population growth, manifesting the need for more urban development to accommodate the large growing population. Through the analysis conducted, we can see cities such as Milton, Burlington and Oakville undergoing urbanization at an increasing rate through analyzing the urban growth of these areas over the last 20 years or so. Thus, it can be extrapolated that these areas are at high-risk of urban sprawl and unsustainable development in the Halton region. Moreover, it is observed that the expansion of residential and industrial areas are approaching closer to the Ontario Greenbelt region which poses a serious environmental threat, as this is suggesting the compromise of protected land under the Ontario greenbelt for more urban development. Lastly, as Halton Region continues to undergo urban sprawl, it is expected to see continuous growth of urban build-up regions at the expense of losing vegetation land areas alarming serious concerns on the sustainability of the environment. Therefore, the effects of urban sprawl in the Municipality of Halton Region need to be understood through advocating sustainable development and taking sprawl mitigation measures immediately.

References

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http://geo2.scholarsportal.info/#r/details/_uri@=692798415$DMTISSV2004HaltonTIFF

Appendix

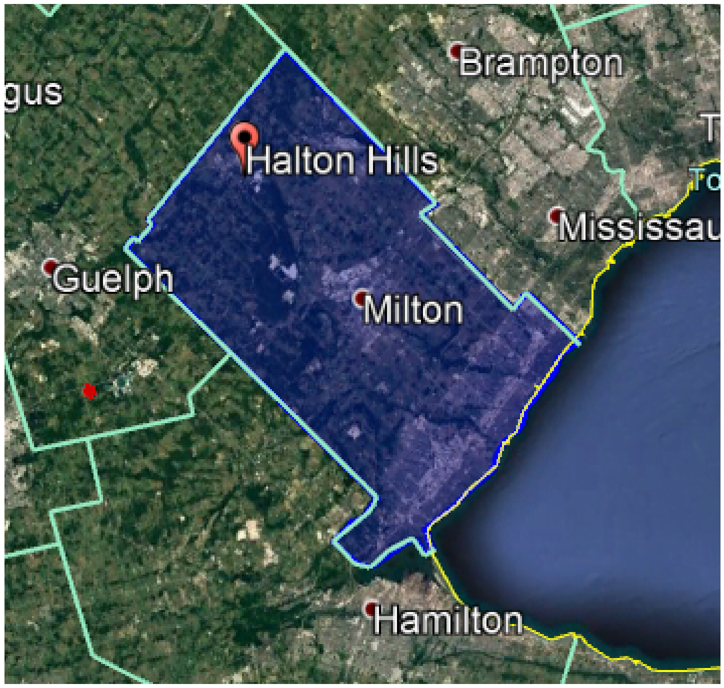

Figure 1. Map of Halton Region Source: Horse Farms Ontario

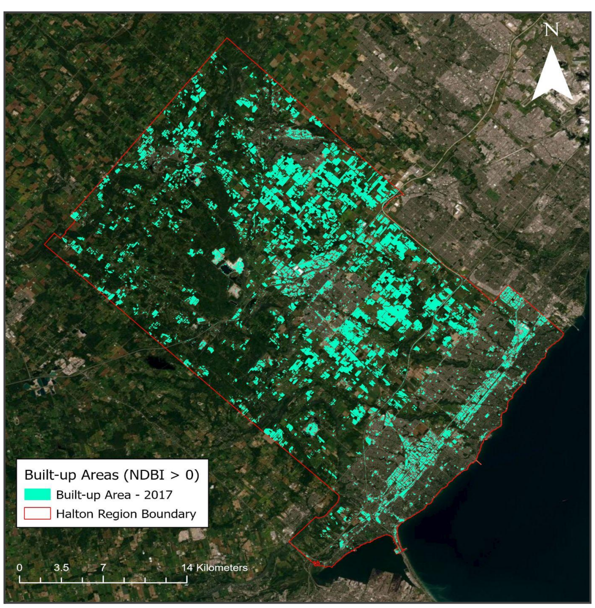

Figure 2. NDBI Urban Areas Calculated (NDBI > 0)

Source: Maps created in geoprocessing analysis

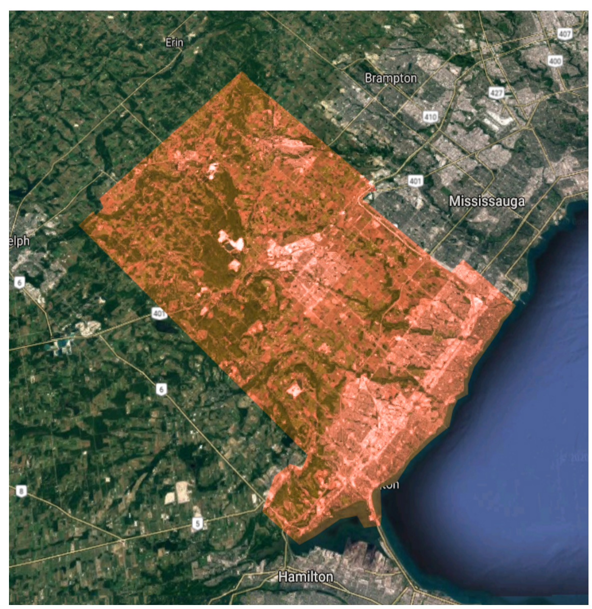

Figure 3. Satellite Image of Halton Municipality

Source: Google Maps

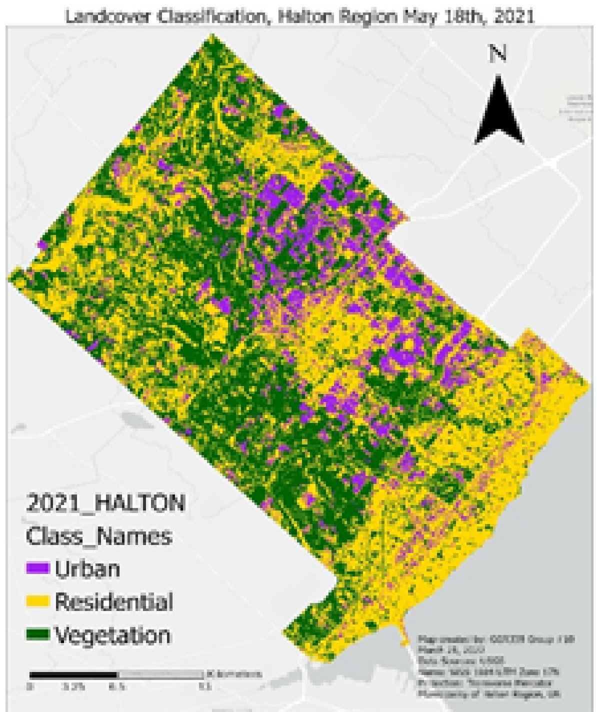

Figure 4. Classified Landcover, Halton Region 2021

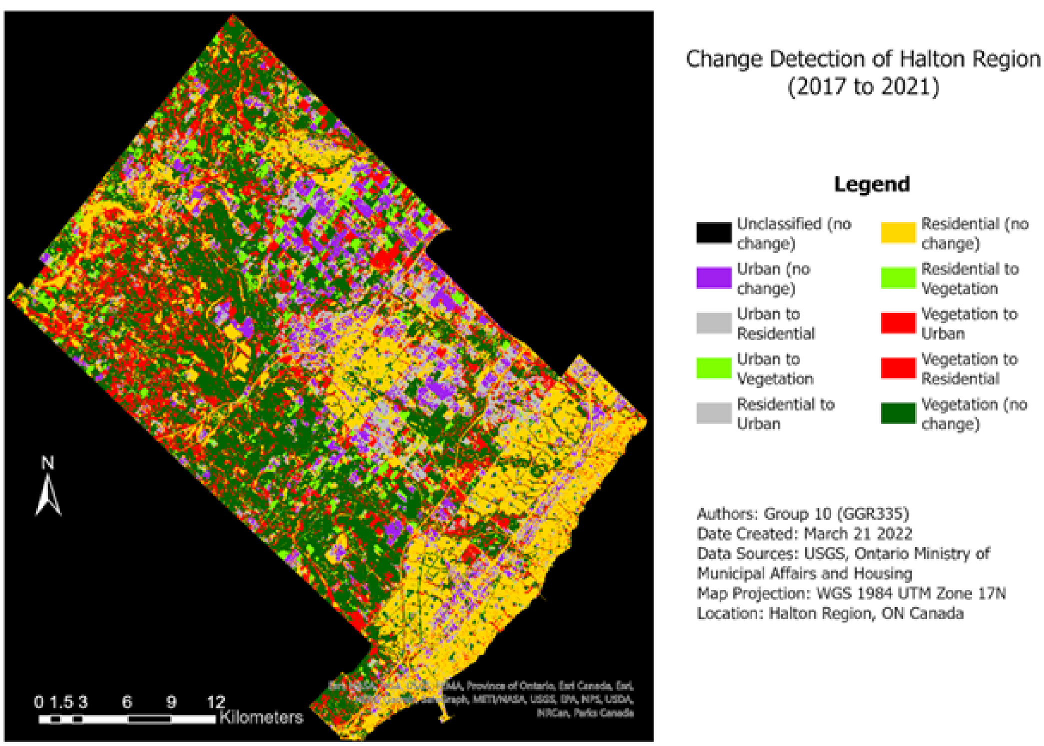

Figure 5. Change Detection of Halton Region (From 2017 to 2021).

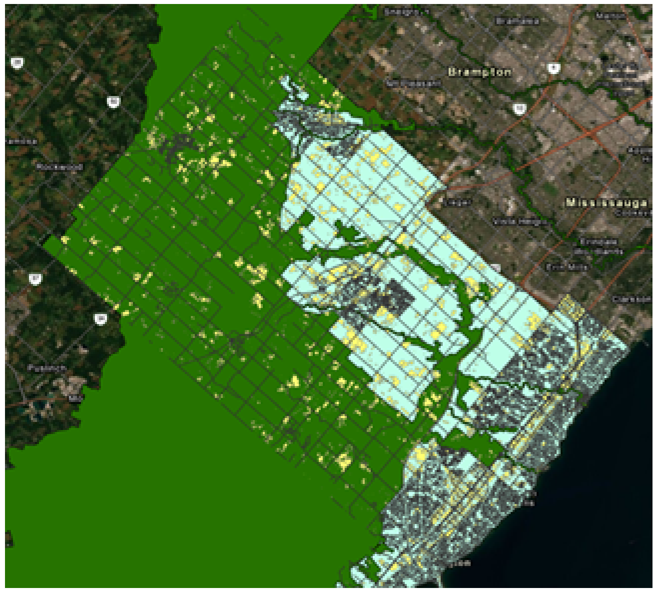

Figure 6. Ontario Greenbelt overlayed onto Halton Region (2006).

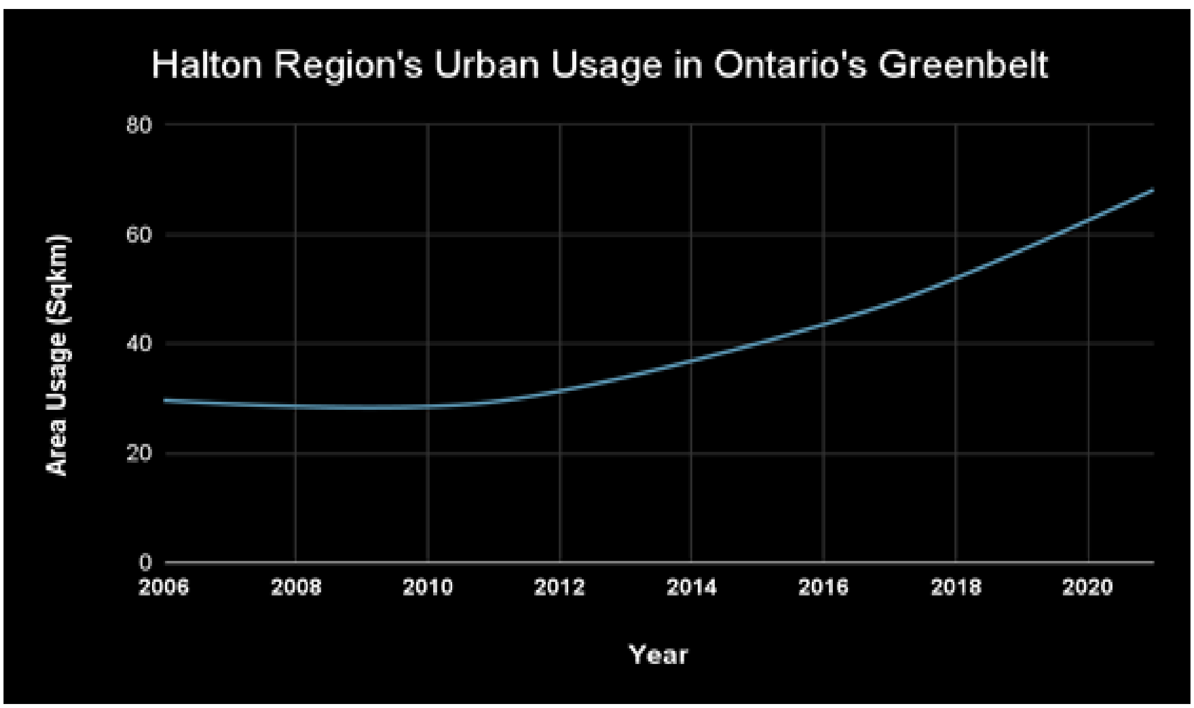

Figure 7. Linear Plot of Halton Region's Urban Usage in Ontario Greenbelt

Table 1. Change Detection of the Halton Region

Row	Histogram	Class_Names	Color	Opacity	area_change_(sqmiles)
0	1395474	Unclassified / no change		0	484.916
1	9796	Urban / no change		1	3.40403
2	10354	Urban to Res / changed!		1	3.59793
3	2193	Urban to Veg / changed!		1	0.76205
4	46976	Res to Urban / changed!		1	16.3238
5	285296	Residential / no change		1	99.1381
6	87693	Res to Veg / changed!		1	30.4726
7	83846	Veg to Urban / changed!		1	29.1358
8	201440	Veg to Res / changed!		1	69.9988
9	346532	Vegetation / no change		1	120.417

Table 2. Chart of Demographic statistics vs Urban Build-up Rate in the Halton Region

Table 1: Demographic vs. Urban Built-up Rate of Halton region					
Year	**Population**	**Population Density (per sqkm)**	**Total Land Area (sqkm)**	**Total Built Area (sqkm)**	**Urban Build-up Rate(%)**
2001	375,229	388.0	967.04	75.9742	7.86%
2006	439,256	454.2	967.17	91.3231	9.44%
2011	501,669	520.4	964.01	93.202	9.67%
2017	548,435	568.9	964.05	142.157	14.75%
2021	596,637	617.8	965.71	202.239	20.94%

Table 3. Accuracy Assessment of Classified landcover map, 2021

	Class types determined from Reference Source					User's Accuracy
Class types determined from Classified Map	# Plots	Urban	Residential	Vegetation	**Totals**	
	Urban	3	0	0	3	100%
	Residential	2	4	3	9	44.44%
	Vegetation	0	0	8	8	100%
	Totals	5	4	11	20	
Producer's Accuracy		60%	100%	72.73%		OA: 75%
Overall Kappa Statistics = 61.69%						