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Recent Land Use Changes on an Urban Watershed in Moncton, New Brunswick, Canada
Changements de l'utilisation du sol depuis 1970 dans un bassin versant urbain de petite taille au Sud-est du Nouveau-Brunswick, Canada

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Article abstract

Changes in land use, which threaten ecosystems and habitats, have an impact on run-off and water quality on urban areas. Using a GIS program we have classified the land use of the Humphreys Brook watershed and quantified the changes that have occurred using landscape metrics. A rapid growth of the city emerges from our results. All land use types of urban nature have seen an increase in surface areas to the detriment of natural land uses. Moreover the landscape indices are showing signs of rectangularity, where humans have introduced straight edges, and other common processes of transformation to the landscape.

Mélanie LeBlanc et Guillaume Fortin

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Introduction

1 Landscape naturally changes over time and space but nothing has had an impact on the landscape as much as human activities (Foley et al., 2005). Recent debates have arisen to place the beginning of the Anthropocene era; the period where humans began having the most significant influence on the Earth systems and climate. Is it when we started forest cutting and agriculture (5000-8000 millennia BP) or is it the industrial revolution (mid-1900s) (Crutzen and Steffen, 2003)? The industrial revolution does coincide with the exponential growth rate of urbanisation, which added stress and altered connectivity of natural resources and landscapes. Land use modifications on urban and suburban areas are related to climate change, pollution and alterations to both biotic and abiotic ecosystem at local, regional and global scales (Foley et al., 2005; Grimm et al., 2008).

2 Urbanization modifies the hydrologic systems within watersheds (Paul and Meyer, 2001; Allan, 2004; Claessens et al., 2006; Lee et al., 2009). It generally increases the proportion of impervious surface, which decreases infiltration and groundwater recharge and changes the patterns of surface and river runoff (Niemczynowick, 1999; Allan, 2004), thus changing the underground water flow (Paul and Meyer, 2001). The increase in pollutants that flows into the river system decreases the biodiversity (Allan, 2004; Deacon et al., 2005). In addition, the urban pollution can have a significant impact on the river's sensitive invertebrate diversity, as does alteration to the riparian vegetation (Walsh et al., 2007). On the other hand, the impervious surface changes the radiative budget because it absorb energy from the sun (short-wave radiation) during the day and releases heat (long-wave radiation) during the night, increasing temperatures, thus contributing to create urban heat islands (Alcoforado and Andrade, 2008). The water balance is also affected by the urban heat island with higher temperatures we experience more evapotranspiration and irrigation. The combination of all these impacts can have considerable effects on the biogeochemical cycles that are controlled by different drivers such as hydrology, atmospheric chemistry, climate, nutrients, vegetation composition and land use (Kaye et al., 2006). Other impacts have been observed with changes in land use. For example: erosion and sedimentation increases (Bernhardt and Palmer, 2007) and increase in nutrient enrichment in storm water runoff, loss of wetlands and alteration in stream morphology (Purdum, 1997; Allan, 2004). The situation can be particularly critical in fast growing urban and suburban regions where changes are happening at a greater rate than proper management methods can be implemented.

3 Knowing that land use has an effect on water quality and the ecosystems, we have to consider that not all land use have equally the same impact on the environment. As stated by Lee et al. (2009), it is important to understand the unique regional characteristics of both human and environmental relationships between land use and water quality. Measuring land use is an indirect method of projecting human activity, which can lead to generalization of the impacts on the environment. Landscape indicators are used as complement to other approach to quantify human impacts on a water system by looking at the changes in land use in the surrounding watershed (Gergel et al., 2002).

4 South-eastern New Brunswick, Canada, is one of those areas that is experiencing rapid population growth. In the last decades, the urban centre of this region: Greater Moncton has grown rapidly. Its population was estimated at 126 404 in 2006 (Statistics Canada, 2011). With a growth rate of 6.5% from 2001 to 2006, Moncton was the 10th fastest growing census metropolitan area (CMA) in Canada and that trend has not been slowing.

5 Urban growth has drastically changed the landscape in the area. As the city and its surrounding towns have spread over time, more and more buildings, residential areas and roads have covered the land. Among the most significant land use/cover changes we have seen: agricultural lands that have been abandoned, forested areas have become residential and/or industrial land, the development of intricate road networks have fragmented what once was natural landscape. Riparian vegetation and woodlands are important as they provide environmental services such as filtration, ground water protection and habitat for different species and, their ability to provide these services are limited by their size, shape and distribution (Kim and Pauleit, 2009). Urbanisation is ultimately changing streams from functioning ecosystems into efficient gutters (Bernhardt and Palmer, 2007).

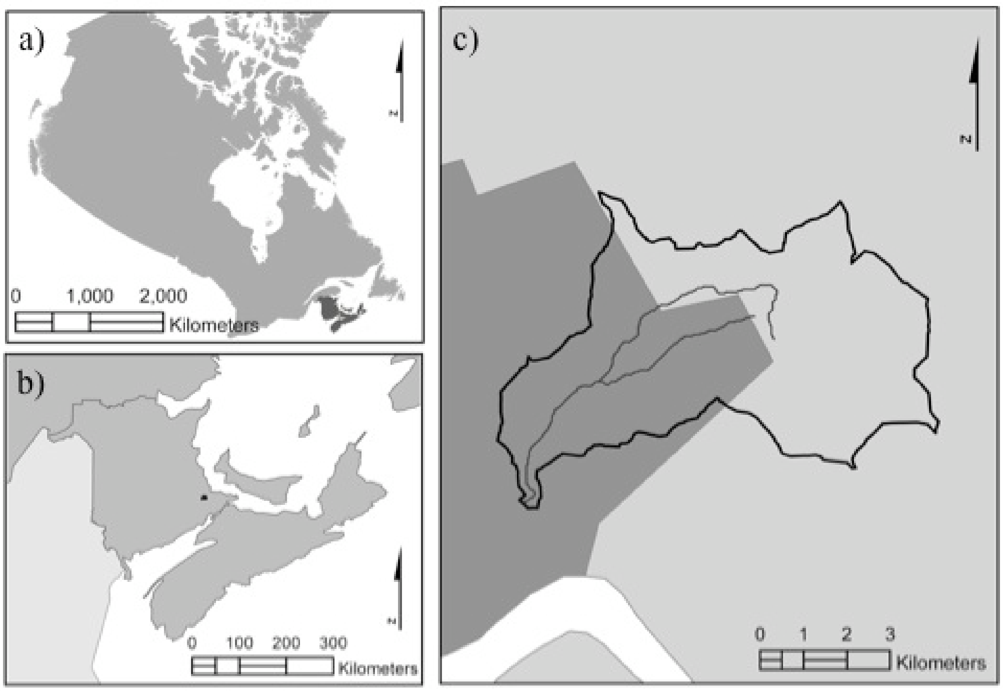
6 This paper presents a case study (Humphreys Brook) to illustrate how urbanization, with the growth of a Canadian mid-size city in the Atlantic region, changes the land use/cover over time in a small watershed. To achieve this goal, diachronic mapping (based on aerial photographs, orthophotomaps and historical maps) was done using Geographical Information System (GIS). The heterogeneous landscape, in the study area, required a manual classification. To improve the landscape characterization, we use landscape indicators (Gergel et al., 2002) to further understand the impacts on the watershed. The two main objectives of this study are the following:

- to calculate the amount of changes over the surface area that has been modified during the study period of 1970-2001 based on aerial photos;
- to quantify the habitats changes (fragmentation, dissection, etc.) that happened in the same time frame.

7 With the results of this study, we will be able to give recommendations on land use management and urban planning; we will also be able to demonstrate areas of greatest concern and suggests methods of mitigation in anticipation of further urban growth.

Study Area

Fig. 1 - Localization of Humphreys Brook watershed a) Maritime provinces of Canada, b) Moncton located in the Maritime Provinces, c) Humphreys Brook watershed with Moncton city limits



8 The study area is the Humphreys Brook watershed, which is located in the Greater Moncton area in the south-eastern region of New Brunswick, Canada (Figure 1). This small watershed has a surface area of 39.65 km^2. Humphreys Brook (a third order stream) is a tributary of Halls Creek, which flows into the Petitcodiac River. The Petitcodiac River is a tidal river which

comes from the Bay of Fundy, where the largest tidal ranges in the world have been recorded (16 meters), this affects the flow of water from the mouth of Humphreys Brook and for a distance of approximately 1.5 km upstream. The tidal influence is currently blocked by the presence of a dam. The study area can be found between the latitudes of 46.162988N and 46.095738N and the longitudes of 64.777396W and 64.648833W.

9 At the head of Humphreys Brook's, we find an area called Aero Lake, which is presently classified as a wetland. While looking at historical maps, we see that the area was once classified as a lake, which can be seen today when water levels are at their highest. The length of the main tributary of the brook is 9.72 km. Humphreys Brook is classified as an urban stream as it flows through the city of Moncton. The main disturbance on this brook is the dam that was built in 1931 to provide water to a textile mill adjacent to the brook. This dam of 9.1 m wide, 4.7 m high and 7.6 m deep, not only stops the flow of water flowing downstream creating a pond above the dam but also stops the tidal flow coming up from the Petitcodiac River. Other anthropogenic disturbances present are: a scrap yard bordering the brook, a newly constructed pedestrian trail, some residential projects (individual or multifamily dwellings), and the expansion of the Caledonia Industrial Estate, Moncton's largest and growing industrial park.

Methods

Data

Historical maps

10 Maps from the area were obtained from the Map Image Rendering Database for Geoscience (MIRAGE) which is an image library of the Geological Survey of Canada maps available on Natural Resources Canada's website (Table 1). Some of the maps found date prior to the incorporation of Moncton as a city, thus giving us insight to the landscape of the past. This information can be useful to identify the changes in the landscape of the area and to identify trends in the land use changes over time.

Table 1 - Historical Maps of Humphreys Brook area.

Year	Map Name	Scale
1886	Province of Nova Scotia and Parts of New Brunswick	1: 253 440
1895	Surface Geology Provinces of Nova Scotia and New Brunswick	1: 253 440
1917	Map 63 A Moncton Westmorland and Albert Counties	1: 62 500
1931	Map 269 A Moncton Sheet Westmorland and Albert Counties	1: 62 500
1941	Map 646 A Moncton Westmorland and Albert Counties	1: 62 500
1965	Moncton	1: 25 000
1966	Lakeburn	1: 25 000
1970	Painsec Junction	1: 25 000
1980	Moncton	1: 50 000

Orthophotomaps and Aerial Photographs

11 Orthophotomaps are created from aerial photographs that are geometrically corrected to remove the effect of the tilt and relief to allow the features to display their true ground position (Service New Brunswick, 2010). The orthophotomaps from 1996 (colour) at a scale of 1:10 000 have been used in this study as a base to georectify the aerial photographs and the historical maps. Like the orthophotomaps, the aerial photographs for the study area are from the New Brunswick provincial department of Natural Resources. Two series of aerial photographs were used in this study: 1970 (monochrome) at a scale of 1:10 000 and 2001 (colour) at a scale of 1:12 500. Aerial photographs from 1982 (colour) at a scale of 1: 12 500 were also used as references. As Provencher and Dubois (2007) have stated the digitization

of aerial photos offers different advantages and facilitates multidates studies, permits an automated acquisition measurements and enhances contrasts. These photographs provide great details in the succession of the landscape of the study area. There are other methods of classification of land use including semi-manual or automated image classifications generally use satellite images that can be used complementary to aerial photographs. Nevertheless semi-manual and automated classifications are generally more suitable for homogeneous land use as for heterogeneous environments that require special attention in order to distinguish the boundaries of different types of land use that may vary over short distance as is the case for urban areas which is the subject of our study. In addition, one of the advantages is that digitized aerial images used in this study is easily available and affordable (Herold et al., 2002).

Data Preparation

12 The historical maps were directly imported into the GIS (ArcGIS 9.2, ESRI) as they were already in a numerical format at a high resolution. Each map was then georeferenced using the orthophotomaps using a minimum of twelve ground control points (GCP). GCP chosen for the historical maps were mostly territorial features such as street corners and other prominent landscape features such as bridges, dams and churches (Stäuble et al., 2008).

13 The aerial photographs were digitized at a minimum resolution of 600 dpi (Hughes et al, 2006; Rayburn and Schulte, 2009) in order to maintain a minimum pixel representation of 1 meter (Hughes et al, 2006) using the following formula:

14 $R_g[cm] = M/R_s[line/cm](1)$

15 Where Rg is the ground resolution, M is the scale of the aerial photograph and Rs is the resolution to be used when digitizing the photograph (Neteler and Mitasova, 2002). Once digitized, they were imported and georectified in the GIS creating a mosaic of aerial photographs of the study area. The georectification of the aerial photographs was done using the same methods as the maps, using twelve GCP (Hughes et al, 2006) within every photograph and matched to the orthophotomaps. The final maps are in vector format.

16 Finally, the GIS program calculated the residual error. A residual error of less than 0.5 was accepted on a third order polynomial model, when the residual error was greater resampling of the GCP was completed (Cousins, 2001).

17 All maps, aerial photographs and orthophotomaps were projected in NAD83 New Brunswick Stereographic Double projection in the GIS program, which is the official projection for the province of New Brunswick, Canada.

Watershed Delineation and Land Use Classification

18 The outline of the watershed was done using TauDEM (Tarboton, 2009), which utilized the digital elevation model to delimit the watershed. Once the watershed delimited, polygons were drawn to delineate the different types of land use within the watershed boundaries. The classes (Table 2) selected for this exercise were based on a combination of the United States Geological Survey (USGS) land classification (Anderson et al., 1976) and the Canadian Land Use Monitoring Program (CLUMP) (Government of Canada, 2010).

Table 2 - Land use classes in Humphreys Brook watershed

Class	Description
Residential	included single and multiple family homes, parks, cemetery
Industrial/Commercial	included airport, golf course, industrial park, shopping centres
Major Roads	limited to Trans-Canada highway, Highway #15, Canadian National Railway
Agriculture	agricultural lands and deforestation
Wetland	included marshes, swamps and wetland
Forest	included mixed forest and dense tree patches
Transitional	Snow dump, construction, quarry, etc.

Land Use and Spatial Characteristics

19 Once the watershed was fully covered with land use polygons, statistical information was extracted from the GIS program for further analysis. The perimeter and the surface area of every polygon were extracted and the patch shape index (SI) was calculated using the following formula:

$$SI_i = \frac{p_i}{2\sqrt{\pi \times a_i}}$$

(2)

20 Where p is the perimeter and a is the surface area of the polygon. The square root in the equation is used for scale-independence (Comber et al., 2003). If the shape index is circular the value is 1 and it will increase as the shape becomes more irregular (Forman and Godron, 1986; Moser et al., 2002, Comber et al., 2003). The shape index is widely used in landscape ecological research and it can be used as an indicator for species richness (Moser et al., 2002), ecological processes (Forman, 1995; Kim and Pauleit, 2005) and also as an index to human activity (Gergel et al., 2002). It has been shown that shape complexity decreases with humans land use activities where humans have introduced rectangularity and straight borders (Moser et al., 2002; Kim and Pauleit, 2005).

21 Additional calculations were done to further understand the spatial characteristics of the land use. For example the Mean Shape Index (MSI), was calculated using the following formula:

$$MSI = \frac{\sum_{i}^{m}=\iota SI_i}{NP}$$

(3)

22 and the Area Weighted Shape Index (AWSI), was calculated using this formula:

$$AWSI = \frac{\sum_{i}^{m} -SI_i \; a_i}{\sum_{i}^{m} = \; a_i}$$

(4)

These metrics allowed further explanations to some of the interactions and influences on the landscape as the SI of a class alone can be misleading if consideration of the landscape is not taken. Calculating the MSI allows us to see the average of the individual patches found in one class (*NP* correspond to the Number of Patches), while calculating the AWSI allows us to account for the possibility of large patches that can be found in certain classes.

23 Over time, the changes that occur in the land use/cover can be classified in one of the following processes of transformation: dissection, fragmentation, shrinkage, attrition and expansion (Kim and Pauleit, 2009; Lee et al., 2009). According to Forman (1995), dissection is where carving up or subdividing an area with equal width lines (roads, power lines, etc.) and fragmentation is the breaking up of a habitat, which is widely and unevenly separated. Shrinkage is referred to when a patch has become smaller (as a result of destruction) (Kim and Pauleit, 2009). Attrition is the result of a patch completely disappearing from the landscape and expansion is the result of a patch size getting larger (Kim and Pauleit, 2009).

Ground Verification

24 In order to come full circle with the study, ground verification was done to validate observations from the aerial photographs and to get further insight into the changes that have occurred from 2001 to present. Field verifications (samples) of the classes that were used in the land use classification are as followed (Figure 2): forest, wetland, agriculture, residential, commercial/industrial, major roads and transitional.

Fig. 2 - Land use classes, a) Forest, b) Wetland, c) Commercial/Industrial, d) Residential, e) Major Roads, f) Agriculture

25 Field verification was an ongoing process that was concentrated in the area adjacent to Humphreys Brook. Many of the verifications came after concerns were voiced to the local watershed group (Petitcodiac Watershed Alliance) in order for them to verify whether the disturbances were compliant to environmental laws. Other field verifications were done throughout the watershed to visualize the changes in the types of land use and to see the changes since 2001.

Results and Discussion

Land Use prior 1970

26 The changes that occurred over the study area prior to 1970 were mainly estimate based on the historical maps. As Gergel et al. (2002) stated quantifying historical land cover could contribute as a useful landscape indicator. The maps demonstrate the expansion of the city from the centre outward, widening its footprint. With these maps it is also visible to see the changes that occurred following the construction of the railway and of major roads, human activities seem to follow these arteries. We can also see the evolution of the landscape types, which follow historical trends from forested to agriculture and further more to residential areas.

Land Use from 1970 to 2001

27 The land use in the Humphreys Brook watershed has changed dramatically in the thirty-two years from 1970 to 2001 (Figure 3). As mentioned previously in section 2.4, the use of the following metrics: SI, MSI, AWSI is useful to improve our understanding of the landscape changes over time in the study area (Table 3 and Table 4). In general, urbanization tends to increase the percentage of major roads, commercial/industrial, residential and transitional lands as well as the degree of landscape diversity and fragmentation (Weng, 2007). The rate of changes is not steady, the early and rapid urbanization have dramatic impacts on landscape patterns, but the rate of urbanization gradually slowed when the availability of land for development decrease. In accordance with this slowing down the degree of landscape

diversity and fragmentation gradually decreased while urban land-use types became dominant (Weng, 2007). As reported by Salavati et al. (2015) several studies considered that a watershed is urbanized when more than 10% of its area is covered by build-up areas. In Humphreys Brook watershed the build-up areas included all the following land use class: commercial/industrial, residential, major roads and transitional in our case and they represent 18.43% in 1970 but increase to 32.18% in 2001 (Table 3). This is an increase of more than 55% over 30 years. The surface coverage should be interpreted with care because the time required for these changes should also be taken into account as mentioned previously. The total number of polygons have increase over time from 226 in 1970 to 258 in 2001 this is an increase of approximately 13%.

Fig. 3 - a) Land use of Humphreys Brook watershed in 1970, b) Land use of Humphreys Brook watershed in 2001

Table 3 - Changes in land use of the Humphreys Brook watershed from 1970 to 2001

	# polygons		surface area (%)		surface area (km^2)		mean patch size (km^2)	
	1970	2001	1970	2001	1970	2001	1970	2001
Forest	60	89	58.64	52.5	23.25	20.82	0.39	0.23

Wetland	15	10	9.07	7.24	3.6	2.87	0.24	0.29
Agriculture	58	31	13.87	8.08	5.5	3.2	0.09	0.10
Residential	41	48	4.91	9.46	1.95	3.75	0.05	0.08
Commercial/ Industrial	19	25	7.65	12.66	3.03	5.02	0.16	0.20
Roads	1	2	1.84	5.17	0.73	2.05	0.73	1.03
Transitional	32	53	4.03	4.89	1.6	1.94	0.05	0.04
Total	226	258	100	100	39.66	39.66	---	---

Table 4 - Results of Land use changes in Humphreys Brook watershed.

	Shape Index[1]		Mean Shape Index[2]		Area Weighted Shape Index[3]	
	1970	**2001**	**1970**	**2001**	**1970**	**2001**
Forest	10.67	14.29	1.82	1.95	2.61	2.78
Wetland	6.03	5.74	2.18	2.26	2.02	2.17
Agriculture	10.59	9.17	1.62	1.85	2.26	2.21
Residential	7.85	8.12	1.47	1.52	2.79	2.52
Commercial/ Industrial	4.18	5.98	1.47	1.5	2.09	1.91
Roads	16.07	10.85	---	6.41	---	10.63
Transitional	11.77	15.39	2.41	1.92	4.23	5.55

[1]SI : if it is circular the value is 1 and it will increase as the shape becomes more irregular; [2]MSI : represent the average of the individual patches found by class; [3]AWSI: this measure provides general information on the landscape structure rather than being centered on the patches.

28 We can see with the SI have increased for forest but not for wetland where a decrease occurs. For urban classes : residential, commercial/industrial and transitional an increase of the SI was observed while for major roads it was rather a decrease. This situation show how complex urbanization has had an effect on the landscape. By looking further into the changes that have occurred on the land use maps and with the metrics we can determine the types of changes (dissection, fragmentation, shrinkage, attrition and expansion) (Table 4).

Fig. 4 - Forested land use of Humphreys Brook watershed in 1970 (a) and in 2001 (b)

29 Forested areas have seen the most dramatic changes between 1970 and 2001. The area covered by forested landscape dropped by 2.43 km^2 (6.14%); we have also seen an increase in the number of polygons (+29) containing forested landscape with a smaller average size of polygon, which shows that much of the forest has been dissected and fragmented (Figure 4). All of the shape indexes show that the forested land use has become more complex (SI: from 10.67 to 14.29; MSI: from 1.82 to 1.95 and AWSI: from 2.61 to 2.78) these show that the landscape has been undergoing human induced changes. The development of new residential and industrial/commercial zones have required more land, therefore forested areas have been under pressure. These areas are generally more susceptible to development than wetlands, which require filling which brings extra costs.

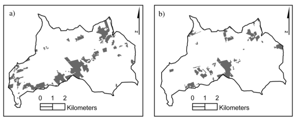
Wetland

Fig. 5 - Wetland land use of the Humphreys Brook watershed in 1970 (a) and in 2001 (b)

30 Wetlands are some of the most productive ecosystems in Canada (Government of New Brunswick, 2002). Unfortunately, in the Humphreys Brook watershed what was classified in the wetland class has seen both attrition and shrinkage in the last three decades (Figure 5). The

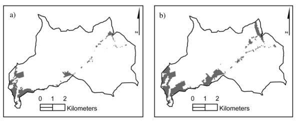
number of polygons has diminished (- 5) and the total surface area has also decreased by 0.73 km^2 (Figure 5). The average size of the wetland polygons has increased from 0.24 km^2 to 0.29 km^2. Larger wetland polygons are good ecologically, but looking at the decreased number of polygons and the increase in the mean size patch this simply demonstrates that smaller wetland patches have completely disappeared from the landscape (Figure 5). Disappearing wetlands are common and alarming in Canada. The province of New Brunswick has already lost over 65% of its coastal wetlands (Government of New Brunswick, 2002). The increase in the MSI (2.18 to 2.26) and the AWSI (2.02 to 2.17) is also a concern considering that the increase is showing a more complex shape to the polygons, which can be linked to human activities. By contrast, the SI decreased (6.03 to 5.74), this is normal because human activity introduced rectangularity and straight borders (Kim and Pauleit, 2005). In the Moncton area, wetlands have previously been used as dump sites, which is a threat to water quality. The underground water tables near wetlands are located close to the surface. The leaching of pollutants from dumpsites can easily reach both surface waters and ground water.

Fig. 6 - Agriculture land use in Humphreys Brook watershed in 1970 (a) and in 2001 (b)



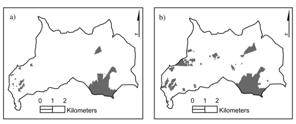
31 A common trend, as the city has grown and developed, is that land that was once reserved for agriculture and livestock are being transformed into residential areas or left to grow wild again. Much of the land that was agricultural in 1970 has been reduced in 2001 (Figure 6). In fact, there was a 2.3 km^2 decrease in agricultural land during this timeframe, with a decrease of 27 polygons (31 in 2001 instead of 58 in 1970). The different shape indexes have declined and with references to figure 3 and figure 6, it is noticeable that the agriculture class has been reduced and taken over by residential and forest. This would explain the differences in the landscape metrics in table 3. The lowered SI and AWSI does indicate that some of the patches have become simpler in shape, which can be explained by some agriculture lands being left to grow wild and the forest boundaries encroaching on the once cultivated land. By looking at the MSI, the higher numbers indicate that most of the patches have become more complex and a good number of polygons would have been transformed to residential areas.

Fig. 7 - Residential land use in Humphreys Brook watershed in 1970 (a) and in 2001 (b)



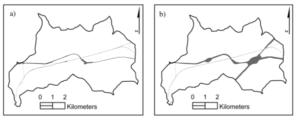
32 As previously mentioned, Moncton has been enduring a rapid population growth. A growth in population often translates to residential areas developing further in the suburban area. The Humphreys Brook watershed is no exception; we can see on Figure 7 the expansion of the residential areas that have progressed further and further away from the city centre. The residential class has grown by 1.8 km^2; this is almost double the residential area from 1970. The higher SI in 2001 would lead us to believe that the growth of the residential areas has been irregular, but by looking at the AWSI we observe that the shape of the residential cluster have simply become larger and more regular. The areas between neighborhoods (other classes such as forest, wetland and agriculture) are gradually being built to residential zones. The southwest part of the watershed is particularly affected by this phenomenon (Figure 7), as is the development along the southwest-northeast axis, which is following a secondary road.

Fig. 8 - Commercial/Industrial land use in Humphreys Brook watershed in 1970 (a) and in 2001 (b)



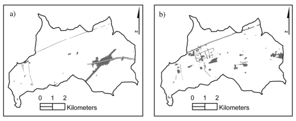
33 The commercial/industrial class has seen some major changes in this timeframe. There has been growth of 1.99 km^2 (Figure 8) in this land use class. The growth has occurred mostly due to the expansion of the Greater Moncton International Airport (southeast portion of the watershed), the expansion to the Lakeside Golf and Country Club (northeast), the Caledonia Industrial Estates (northwest) and the many businesses closer to the city centre. Like the residential class, the SI has grown showing an increase in the complexity of the polygons, while the AWSI have gotten smaller demonstrating more regularity to the landscape.

Fig. 9 - Major Roads land use in Humphreys Brook watershed in 1970 (a) and in 2001 (b)



34 The arterial roads in this area has experience some expansion (Figure 9). The Trans-Canada Highway was widened to a 4-lane highway and the construction of a new 4-lane highway (HWY15) was completed. The total land covered by arterial roads has increased to 2.05 km^2 from 0.73 km^2, and although the amount of polygons have gone from 1 to 2, it is important to note that because of the nature of the road network, these polygons are in the same network, but the connecting road (HWY15) passes outside the watershed boundaries before re-entering. The decrease in the SI is again directly linked with the increase in size of the polygons. Further, even if the total surface area occupied by roads is not major when compare to other land use classes it can have serious impacts in sediment and pollutant loads depending on the landscape and distance between the stream channels and the roads for example as recently shown by Pechenick et al. (2014). In addition, ecological connectivity can be disrupted in water bodies that are dammed or crossed by roads but this cannot be easily distinguished by the metrics that we used. Freeman et al. 2007 illustrate mechanisms by which the cumulative alteration of headwater streams is likely to affect ecological function at larger scales. The Humphreys Brook is a stream where the headwaters plays an important role at a regional scale. A decrease of water quality and quantity of headwater streams can create different problems at a larger scale such as downstream eutrophication, lower secondary productivity of river systems and reduce viability of freshwater biota (Freeman et al., 2007).

Fig. 10 - Transitional land use in Humphreys Brook watershed in 1970 (a) and in 2001 (b)



35 The class transitional consists of a class that for the most part is temporary or transitional (Figure 10). Anderson et al. (1976) mentioned that this class is useful when neither the former nor the future use can be discerned and the area is obviously in a state of land use transition, it is considered to be barren land, in order to avoid inferential errors. Moreover this class is particularly appropriate when few information to characterize the land use is available to the land use interpreter to predict reliably the future use or discern the past use.

36 For that reason it is difficult to analyze the metrics for this class as much of this class's polygons from 1970 are not the same polygons in 2001 that have undergone changes but rather completely different polygons. In 1970, the majority of the surface area that was covered by this class was the construction site of a 4-lane highway that, in 2001, cuts across the watershed. By 2001, the highway was completed and is now in the class major roads and the majority of the class transitional in the Caledonia Industrial Estate where they are heavily expanding this industrial park.

Land Use from 2001 to present

37 Since 2001, the Greater Moncton Area has continued to grow exponentially creating further pressure on the environment. Sometimes, development is done with consideration to the impacts that can occur with construction and changes to the landscape, other times it seems like the environment is completely dismissed.

38 Other major changes in the Humphreys Brook watershed, since 2001, would be the expansion of the Caledonia Industrial Estates, which went from phase 1 to phase 3, and the construction of a new airport terminal at the Greater Moncton International Airport.

39 Areas of concern in the Humphreys Brook watershed can be found throughout the area. Signs of disturbances can be found all along the stream. In the lower portion of the stream, a dam, which blocks the natural flow of water, has drastically changed the ecosystem directly above. At the mouth of the stream, a highway passes just meters away which increases pollution into the stream as does two snow dumps used during winter clearing of the snow which overflow into the stream. Along Humphreys Brook is a sewer line that in times of heavy rain, have been known to overflow directly into the stream at many different points. Infilling of wetlands and new developments are continuous threats if proper management and mitigation methods are not put into place.

Conclusion

40 The result of this study showed that land use/cover of the study area is particularly dynamic and is not unusual for this type of mid-size urban area in the Atlantic region. Although most of the changes we have observed have been anthropogenic, some have been caused by natural progression of the landscape and some as a reaction to changes in land use in adjacent patches. Appropriate land use decisions should consider the impacts that development have on water quality and that since rivers and streams are complex systems it must be looked at a greater scale.

41 So with the visual changes seen on the aerial photographs in combination with landscape metrics, we have a better understanding of the ecological impacts these actions can have. Those changes can be used as a lesson for the future to minimize detrimental actions that could have negative impacts on the watersheds, streams and ecosystems of the urban and peri-urban area.

42 Our results for the Humphreys Brook watershed indicate that urbanization has played a serious role in the changes of the land use/cover. Natural land use (forest and wetland) has seen dissection (by major roads), fragmentation shrinkage and attrition that have caused a decline of 3.16 km^2 (-7.97% of the total surface area) while urban land use (residential and industrial/ commercial) has known an expansion of approximately 3.79 km^2 (9.56% of the total surface area). The number of polygons had known an increase of more than 13% during the study period. The trend in this area has not slowed since 2001, here we are 10 years later and new developments are being built at a rapid pace. Many of these, seem not to consider the cumulative impacts to the stream below, nor the intricate network of streams, rivers and ecosystems that work together as a whole.

43 Future development is inevitable, but proper management methods and sustainable development can promote a healthier environment. Maintaining a healthy riparian zone for the stream by respecting the minimal buffer zone (30 metres in New Brunswick) protects both water quality and wildlife. Recommendations for future development projects in the area would be to respect the environmental guidelines that are already in place and to ensure sustainability. Furthermore, Humphreys Brook would greatly benefit from restoration of some of its riparian zones and from the preservation of its wetlands.

44 Unfortunately more recent aerial photographs are not yet available to quantify these changes, but could be something to be considered for future projects.

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Pour citer cet article

Référence électronique

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Droits d’auteur

Résumés

Changes in land use, which threaten ecosystems and habitats, have an impact on run-off and water quality on urban areas. Using a GIS program we have classified the land use of the Humphreys Brook watershed and quantified the changes that have occurred using landscape metrics. A rapid growth of the city emerges from our results. All land use types of urban nature have seen an increase in surface areas to the detriment of natural land uses. Moreover the landscape indices are showing signs of rectangularity, where humans have introduced straight edges, and other common processes of transformation to the landscape.

Changements de l’utilisation du sol depuis 1970 dans un bassin versant urbain de petite taille au Sud-est du Nouveau-Brunswick, Canada

L’urbanisation a divers impacts sur l’environnement. Une classification de l’utilisation du sol a été réalisée à l’aide d’un SIG pour le bassin versant du ruisseau Humphrey. Nos résultats indiquent une croissance rapide de la ville, qui figure d’ailleurs parmi les plus villes ayant le taux de croissance le plus rapide au Canada. Tous les types d’utilisation du sol qui caractérisent le paysage urbain ont connu une hausse au détriment des types plutôt naturels. Finalement des indices du paysage ont permis de détecter des signes de rectangularité résultant d’activités humaines.

Entrées d’index

Mots-clés : utilisation du sol, photographies aériennes, SIG, paysage urbain, bassin versant
Keywords : land use, aerial photographs, GIS, urban landscape, watershed