1. Introduction

There is an increasing need for cities to put more efforts into insuring a healthy environment for their citizens, as more than half of the world's population now lives in urban areas (United Nations 2008). The role of vegetation in cities is receiving greater attention because of its ecological services, such as mitigation of urban heat islands, air and noise pollution and runoff water from storms (e.g. Whitford et al. 2001; McPherson et al. 2005). Especially important for urban residents, green spaces in cities also offer opportunities for mental relaxation, physical exercise and social integration, and hence contribute to improving citizens' health and quality of life (Takano et al. 2002; Seeland et al. 2009; Lee and Maheswaran 2011). In addition, as cities are facing increasing extreme heat events and heat islands related to global warming (IPCC 2007), vegetation planting and greening efforts are becoming an appealing strategy for urban temperature reduction. Governments are increasingly reorienting their urban-forest and green-space management activities toward improving the provision of ecosystem services (Young 2010).

Unfortunately, evidence shows that in many cities, vegetation is unevenly distributed (e.g. Talarchek 1990; Perkins et al. 2004; Heynen et al. 2006). An increasing number of researchers find that the spatial distribution of vegetation disproportionately favors certain socio-demographic groups over others, thus raising environmental equity concerns (Perkins et al. 2004; Heynen et al. 2006; Landry and Chakraborty 2009; Tooke et al. 2010). These findings suggest that cities should address urban vegetation disparities, and researchers are beginning to develop tools that can help communities prioritize tree planting locations based on the provision of ecosystem services as well as socio-demographic distributions (Locke et al. 2010). Recent literature has been showing that numerous factors influence the distribution of urban vegetation, including the built environment as well as socio-demographic drivers on household, neighbourhood and jurisdictional scales (Mennis 2006; Luck et al. 2009; Landry and Pu 2010; Conway et al. 2011; Kendal et al. in press). Thus, in order for cities to both increase ecosystem services and address environmental equity, it remains important to understand how to improve the vegetation cover given the distribution of socio-demographic groups, the constraints of the built environment, and the effects of intra-urban administrative jurisdiction.

In this paper, we examine the effects of such predictors on the distribution of urban vegetation in Montreal (Canada). Previous evidence from Montreal documented disparities in urban vegetation (Pham et al. 2011; Pham et al. 2012) and heat islands (CIHI 2011), and increasing public health problems caused by heat islands (Smargiassi et al. 2009). The implications of the factors explaining the uneven vegetation in Montreal are discussed within the context of the City's ability to both increase ecosystem services and address environmental equity through vegetation management.

2. Literature review and research design

The distribution of vegetation has been associated with characteristics of urban form that determine the space available for planting, such as parcel size, housing type, building density, population density or the distance to the city center (McDonnell et al. 1997; Mennis 2006; Conway and Hackworth 2007). Neighbourhood age or parcel development is also widely discussed in studies of urban vegetation (Smith et al. 2005; Mennis 2006; Conway and Hackworth 2007; Troy et al. 2007; Landry and Pu 2010). The relationship between the age of development and vegetation has been found to be non-linear (e.g. Grove et al. 2006a; Landry and Pu 2010) and the relationship between neighbourhood age and tree cover versus lawn cover could be different (Smith et al. 2005; Boone et al. 2010). In addition, the amount of vegetation differs with respect to land use, such as in industrial zones, commerce, or public parks (Mennis 2006; Conway and Hackworth 2007).

Socio-demographics play a central role in explaining the distribution of vegetation (e.g. Talarchek 1990; Heynen and Lindsey 2003; Troy et al. 2007). Vegetation can be affected directly by household-level landscape decisions or indirectly through support for public or private management efforts. These factors in turn can be influenced by complex mechanisms like economic power, attitude (Schroeder et al. 2006; Zhang et al. 2007), cultural preferences (Fraser and Kenney 2000), group-identity (Zmyslony and Gagnon 1998; Robbins et al. 2001) and race-based discrimination (Heynen et al. 2006). Impacts of those socio-demographics are often important on household and neighbourhood scales (Grove et al. 2006a; Chowdhury et al. 2011).

A few factors are also found to be associated with unevenness of urban vegetation but their impacts can only be observed on larger scales. At an intra-city administrative level such as a borough, public agencies play an important role in the distribution of trees, for example when tree protection regulations restrict the removal, pruning or planting of street trees (Schmied and Pillmann 2003). In addition, past or present land-management public policies associated with different jurisdictional units can affect the distribution of urban vegetation (Landry and Pu 2010).

In light of this literature, understanding the built, socio-demographic and administrative factors affecting urban vegetation is crucial to developing efficient greening strategies, predicting the extent of residential and public vegetation and eventually guiding land-use policy related to urban development at the intra-urban level. The goal of this study is to complement the results of previous studies by looking more closely at urban vegetation in Montreal. Two research questions are addressed: How can the built environment, socio-demographic factors and administrative boundaries predict the distribution of trees/shrubs and lawn? How do these factors differ in their effect on street vegetation versus residential vegetation?

We examine trees and shrubs separately from lawn because of differences in their ecological impacts (Whitford et al. 2001), preferences towards them (Kuo et al. 1998; Bjerke et al. 2006) and their economic benefits (Des Rosiers et al. 2002). We also separate public (street) and private (residential) vegetation. For public vegetation, we include trees along streets (including residential streets) because they are planted and maintained by the city and generally accessible to all residents. For private vegetation, we include vegetation in residential yards (including yards in large complexes of apartments) that is typically planted and maintained by property owners. Separating public and private is important to understanding how the factors associated with vegetation distributions differ according to ownership regimes, which in turn may have implications regarding the design of greening programs (Troy et al. 2007; Kendal et al. in press).

In order to determine the effects of place-based policies and programs, we use administrative borough boundaries as a proxy for borough differences in historic land-management policy (e.g., some boroughs used to be separate municipalities) and investment by public agencies. Boroughs in Montreal are politically and administratively part of the city but they do not have the authority to levy tax. Since January 2002, they have been responsible for local services such as roads maintenance, garbage collection, recreation, parks, culture, and community development (Collin and Robertson 2005). We suggest that using borough names as independent variables would allow us to capture effects of land-use management, public services and other important differences between boroughs.

3. Study area

The study is conducted in the former City of Montreal, including only the territory it had prior to the municipal mergers of 2002 (chosen based on the availability of property and building footprint data). Located on the island of Montreal, the former City is composed of nine boroughs totaling 149 km^2 (Fig. 1). In 2006, more than one million people inhabited this area. The population density varied from 120 000 inhabitants/km^2 in the borough of Le Plateau-Mont-Royal to 5 000 inhabitants/km^2 on the outskirts.

<<**Fig. 1.** Study area: borough boundary and variations in population density and vegetation cover of the former City of Montreal>>

This area was predominantly (i.e., 64% of the dwellings) composed of apartments in buildings with fewer than five storeys; 14% of dwellings were apartments in duplexes which are defined as two dwellings, located one above the other; 10% were single- and semi-detached houses and 8% were apartments in highrise buildings (Statistics Canada 2006). Vegetation covered about 25% of the study area, trees/shrub and lawn occupied about 10% and 15%, respectively (Pham et al. 2011). Vegetation was found in various types of green spaces, such as in parks, golf courses, cemeteries, vacant land, and private yards as well as along streets and alleyways. In addition, vegetation cover, the built environment and socio-demographics vary significantly across the boroughs (Table 1).

<< Table 1>>

4. Methodology

4.1.Data

Our statistical analysis used the Dissemination Area (DA) as the unit of analysis – analogous to the US block group level and used frequently by researchers examining Canadian spatial patterns (e.g. Conway and Hackworth 2007). A DA is composed of one or more city blocks with a population ranging from 400 to 700 people (Statistics Canada 2006). Some researchers have suggested that finer units of analysis to capture parcel-specific difference (Landry and Pu 2010; Sung 2012). Although using DA as the unit of analysis prevents us from examining potentially important differences in built and socio-demographic effects between parcels, we have opted for this unit because socioeconomic status is relatively homogenous throughout a DA and this is the smallest level at which socioeconomic data provided by Statistics Canada is available.

Vegetation cover was identified from three QuickBird satellite images (acquired in September 2007, 60 cm resolution). A classification was applied to the images in eCognition 8.1 in order to identify two classes of vegetation: *trees/shrubs* and *lawn* (see Pham et al. 2011) (Fig. 2). We also created another class called *vegetation*, which is the sum of *trees/shrubs* and *lawn*. Three dependent variables were calculated: the proportion of DA covered by total vegetation, trees/shrubs and lawn (Table 2).

<<**Fig. 2.** QuickBird image, vegetation classification, street vegetation cover and yard vegetation cover of a DA . In 2006 population density was 11 725 inhabitants/km^2. Dwelling types were predominantly apartments in buildings with fewer than five storeys (67%) and apartments in duplexes (32%)>>

<< Table 2>>

Spatial data available in geographic information systems (GIS) format from the City of Montreal included cadastral (i.e. parcel) data, building footprints, streets and parks. We selected parcels containing residential buildings and subtracted from them the buildings' footprints to obtain the space available for planting. In Montreal, this space is usually found behind buildings; we named it *backyard* for the sake of simplicity. Maps of backyards, streets and parks were used to calculate three other dependent variables: the proportion of streets within the DA covered by trees/shrubs and backyards within the DA covered by trees/shrubs and total vegetation (Table 2).

4.2.Variable selection

The built environment was examined through five variables. As a measure of the density of the built environment and relative space available for planting (Conway and Hackworth 2007; Troy et al. 2007), we used population density. Population density was the ratio of inhabitants to land area for each DA, and we used a square root transformation for reasons of normality (**SqrtDens**). As a measure of the urban-rural gradient, we used the distance from the centroid of each DA to the centroid of Place

Ville-Marie representing the city center (**Dist_CBD**). As for land-use types, parks represent the primary land-use type that can may have a large impact on vegetation cover in a populated DA. The proportion of parks in each DA was computed from the park map (**Park_PCT**). Neighbourhood age was obtained from the property parcel map by computing the median age of residential parcels weighted by parcel area to prevent data from being skewed by very large or small parcels (**MedAge**). We also took the square of this variable (**MedAge^2**) to estimate its non-linear effect on vegetation (e.g. Troy et al. 2007). Finally, to examine the effects of different housing types, we used principal components analysis with Varimax rotation, because we detected multi-collinearity of the measures of residential housing types (e.g. percentage of detached housing, percentage of duplexes, etc.). Three factors were retained according to their eigenvalue (higher than 1), which explain 73% of the data variance (Table 3): the presence of detached houses (**Factor 1**), of apartments in buildings that have five or more storeys (**Factor 2**), and of apartments in duplexes (**Factor 3**).

<< Table 3 >>

Socio-demographic variables were selected based on previous studies of urban vegetation (e.g. Troy et al. 2007). We used four variables: percentage of renters (**Renter**), median gross income of households (**MedInc**), percentage of university degree holders (**UniDeg**) and percentage of recent immigrants who arrived in Canada between 1996 and 2006 (**RecImmi**). Administrative borough factors are represented by Montreal borough names. Using Ville-Marie as the reference borough because its vegetation is the least abundant (Table 1 and Fig. 1), we introduced a series of dummy variables denoting whether a DA is located in a given borough or not. All variable names and descriptive statistics are reported in Table 4.

<< Table 4>>

4.3. Regression diagnostics and analysis

To examine the effects of independent variables on vegetation cover, we used a two-step process to conduct statistical analysis. We first used ordinary least square regressions (OLS) models that included all the independent variables. A few regression diagnostics have been done in order to examine if the OLS models are robust enough. More specifically, we investigated multi-collinearity of variables by using the variance inflation factor (VIF) (Chatterjee and Hadi 2006). All the VIF values are lower than 5, confirming that there was no multi-collinearity between predictor variables. We also detected and dropped highly influential observations (i.e. outliers) by using the Cook's distance which measures the difference between the fitted values obtained from the full data and the fitted value obtained by deleting the *i*th observation (Chatterjee and Hadi 2006). We then examined the spatial autocorrelation of OLS regressions by using Moran's I on residuals of OLS results (Lloyd 2007).

To control for spatial autocorrelation (if present) and avoid incorrect interpretation of OLS model results, in the second step we used spatial autoregressive models (SAR) (Anselin and Bera 1998) with the same dependent and independent variables. We computed two spatial autoregressive models in GEODA (Anselin 2005): one in which the *y* variable is spatially lagged (spatial lag model, SAR_{lag}, equation 1) or one with spatially autocorrelated errors (spatial error model, SAR_{err}, equation 2) (Anselin and Bera 1998).

$$y = \rho W y + X\beta + \varepsilon \quad [1]$$

$$y = X\beta + \lambda W(y - X\beta) + \varepsilon \quad [2]$$

Where y is the vegetation indicator, X is the independent variables; β is the vector of slopes associated with X; ε is a vector of error terms; W is the spatial lag term; ρ is the spatial lag coefficient, and λ is the spatial error coefficient.

The spatial weights matrix was calculated using queen contiguity (i.e. considering all surrounding DA that have a common border or common vertices with the observation of interest) (Anselin 2005) because DA in our study area are relatively similar in shape and size. The choice of spatial lag or spatial error for each model was based on the value of Moran's I and the Lagrange Multiplier and Robust Lagrange Multiplier tests (Bera and Yoon 1993) calculated using the residuals from the OLS models.

5. Results

Although Pseudo-R^2 of SAR models are not directly related to the variance explained by the models, it can be used to compare the relative power of each model. The DA models have a higher Pseudo-R^2 than the street and backyard models. Among the DA models, the lawn cover model had a greater explanatory power than the tree/shrub cover model (Pseudo-R^2 0.769 and 0.673, respectively). However, between the two backyard models, the tree/shrub model had greater explanatory power than the total vegetation model (Pseudo-R^2 0.644 and 0.621, respectively). Finally, between the two trees/shrubs models, tree/shrub cover in backyards is better explained than tree/shrub cover in streets (Pseudo-R^2 0.644 and 0.549, respectively).

5.1. Comparing effects between variables in DA models

In the three models using vegetation aggregated for the full DA (Table 5), spatial dependence is significant and substantial in all models, with a positive effect. Among the factors related to the built environment, population density is the second most important factor in the lawn model (with a negative effect), but not significant in the trees/shrubs model. The presence of parks is positive and significant in all three models and it is by far the most important predictor in the lawn model. Distance to city centre is also positive and significant in all DA models and is a slightly stronger predictor in the lawn model. Neighbourhood age (with a non-linear effect) is also significant in all three models, but its explanatory power is higher in the trees/shrubs model. The first housing factor, representing the presence of detached houses, is positive and significant in all three model and it is the most important predictor of tree/shrub cover. The second factor, representing the presence of high-rise buildings, is only significant at $p<0.05$ in the trees/shrubs model with a negative effect.

As for socioeconomic factors, the proportions of renters and university degree holders are positive and significant predictors of lawn cover but only at $p<0.1$. In the trees/shrubs model, neither the presence of renters nor the median income is significant, but the percentage of recent immigrants has a negative effect and the proportion of university degree holders has a positive effect ($p<0.01$).

<< Table 5>>

Significant borough effects vary in magnitude, but do not vary in direction in any of the three models. In the trees/shrubs model, three boroughs have a positive impact (Côte-des-

Neiges–Notre-Dame-de-Grâce, Ahuntsic-Cartierville and Sud-Ouest labeled as 3, 7 and 2 on Fig. 1, respectively). This means even after controlling for the built environment and socio-demographic factors, tree/shrub cover in these three boroughs tends to be higher than in the reference borough, Ville-Marie. One of the suburban boroughs, Rivière-des-Prairies–Pointe-aux-Trembles (8 on Fig. 1) has a negative impact on tree/shrub cover. In the lawn model, Sud-Ouest, Côte-des-Neiges–Notre-Dame-de-Grâce and Mercier–Hochelaga-Maisonneuve (2, 3 and 9 on Fig. 1) have a positive and significant effect while Villeray–Saint-Michel–Parc-Extension (6 on Fig. 1) has a negative effect.

5.2. Comparing effects between variables in backyard and street vegetation models

Spatial dependence is also significant and has a positive effect in backyard and street vegetation models (Table 6). Distance to city center is significant in the backyard models with a positive effect, but not in the street model. Between the two backyard models, the effect of this factor is higher on total vegetation than on trees/shrubs. As expected, population density has a significant and negative effect on backyard indicators. Interestingly however, it has a positive effect on street vegetation. The effect of neighbourhood age on both backyard and street vegetation is significant and relatively similar in both models. All three housing factors are significant and their Z-values are similar in the three models. The presence of detached houses and duplex buildings has a positive effect whereas the presence of apartments in high-rise buildings has a negative impact.

<< Table 6>>

Among socio-demographic factors, the proportion of renters has a positive and significant in the two backyard models, but not in the street trees/shrubs model. The proportion of recent immigrants shows a significant and negative relationship with trees/shrubs cover and vegetation cover in backyards ($p<0.05$) and, to a larger extent, on trees/shrubs cover in streets ($p<0.01$). The proportion of university degree holders is only significant at $p<0.1$ in the backyard trees/shrubs model and it is not significant in the backyard vegetation model. However, it has a strong positive effect on street trees/shrubs cover. Surprisingly, household income is not significant in any of the three models.

Finally, backyard trees/shrubs and vegetation and, to a lesser degree, street trees/shrubs cover are significantly higher in Côte-des-Neiges–Notre-Dame-de-Grâce and Ahunstic-Cartierville than the reference borough. Again, Rivière-des-Prairies–Pointe-aux-Trembles shows a negative relationship with both backyard indicators, as in the DA models.

6. Discussion

We will first discuss the vegetation dataset used in this study. Backyard vegetation and trees/shrubs were computed as the proportion of space available for planting, based on the *a priori* assumption that vegetation cover would be strongly correlated with space available for planting (Troy et al. 2007; Landry and Pu 2010), and we were interested in understanding how other built environment variables related to vegetation cover. In addition, unlike other cities where single-storey buildings may be covered by tree canopy, less than 5% of residential parcels in Montreal have tree canopy extending over the building footprint. We thus caution the reader that our standardization approach would likely require modification when applied to study areas with significant numbers of tree-covered roofs.

Spatial dependence observed in all the vegetation indicators is significant in all models, which is consistent with previous work (Landry and Chakraborty 2009; Kendal et al. in press). This confirms that urban vegetation tends to be spatially autocorrelated, which results from various ecological, historical and social processes. This finding points to the complexity of accounting for the prevalence of urban vegetation (especially street trees), and the related difficulty of developing a quantitative model that includes all relevant explanatory variables and thus would not suffer from spatial autocorrelation (i.e. the elusive "perfect model" alluded to by Lloyd (2007)).

6.1. Effects of the built environment

The strength of built-environment variables (e.g. the distance to the city centre, the presence of parks and population density) with respect to vegetation indicators tends to be higher than socio-demographic variables (Tables 5 and 6), especially when predicting the presence of lawn. One possible explanation is that lawn is more prevalent in suburbs (i.e. greater distance to city center and lower population density) and other areas that have areas of land available for large public parks. These results confirm the work of previous authors (Mennis 2006; Troy et al. 2007; Kendal et al. in press) who also underline the built-environment factors as critical determinants of vegetation.

A closer analysis of street trees/shrubs versus residential vegetation suggests that the commonly established ideas about the role of distance and population density in shaping urban vegetation (i.e. less vegetation in a higher-density urban core) hold true for residential vegetation, but not for street trees/shrubs (i.e. more street trees/shrubs in a higher-density urban core). Additional research would be necessary to investigate the reasons for these differences. However, there are at least several possible questions that might be worth considering when planning such research. Does the relative lack of backyard planting space in areas of high population density lead to greater public pressure for street tree planting initiatives? In suburbs where sidewalks are often absent, are the shade benefits to pedestrians provided by street trees less important when the lack of sidewalk itself presents a barrier to pedestrian traffic (see Evans-Cowley 2006)? Does a desire by suburban residents to create an outdoor living space (Larson et al. 2009) lead to landscape decisions that favour lawn over tree cover in order to accommodate specific backyard activities? Qualitative research may help to address these questions and provide valuable information to understand the factors at play.

Not surprisingly, presence of detached houses and duplexes are important predictors of backyards, street trees/shrubs and DA trees/shrubs. This result is consistent with previous research that found higher canopy cover in areas with a higher proportion of single-family homes (e.g. Troy et al. 2007) or a lower housing unit density (e.g. Landry and Pu 2010). Recent research by Conway et al. (2011) has also found greater involvement in tree planting programs in neighbourhoods dominated by single family homes. In contrast, the presence of high-rise buildings is a significant negative predictor of all trees/shrubs. Future research may hence elucidate the importance of housing type, focusing on the preferences and behaviours of residents who choose those types of housing (Grove et al. 2006b).

6.2. Effects of socio-demographic status

Although socio-demographic factors were important predictors of trees/shrubs, they were only weak predictors of lawn cover (Table 5). This finding emphasizes again the importance of the built environment as a limiting factor affecting where large lawn cover is possible, similar to the "possible stewardship" distinction made by Troy et al. (2007). However, a limitation inherent in remote sensing analysis may partly explain our result; top-down remote sensing techniques cannot detect lawns present underneath a tree canopy. A more robust analysis of the factors explaining lawn cover would require leaf-off imagery or ground-based measurements, which unfortunately were beyond the scope of this study.

Three socio-demographic factors will be discussed in detail. First, the percentage of recent immigrants was a negative predictor of all vegetation indicators (except DA lawn) at varying degrees. It is possible that for recent immigrants, vegetation may not be an important priority in housing selection and they may pay less attention to the greening programs available in their neighbourhood (e.g. Perkins et al. 2004). Second, education status (percentage of university degree holders) was a positive predictor of backyard and street trees/shrubs. Educated residents may be more likely to be aware of and take advantage of tree planting programs (Luck et al. 2009). In addition, educated residents may possess greater social capital to influence private and public street tree planting in their neighbourhoods (e.g. Merse et al. 2009). From an environmental equity perspective, the fact that recent immigrants and less educated residents have a disproportionately lower amount of vegetation raises a question of equity in benefits provided by vegetation. Cities that wish to address this potential inequity and increase ecosystem services, such as reduction of heat island effect, may need to modify their greening programs in neighbourhoods predominantly characterized by these two groups of population (Kendal et al. in press).

Third, after controlling for factors related to the built environment and other socio-demographic variables, renters tend to have more residential vegetation. This may be explained by an important mixture of housing types in certain neighbourhoods of Montreal: high-rise buildings inhabited by renters could be located next to numerous owner-occupied detached houses with large gardens. Our results may be hence skewed because vegetation cover would likely be inflated in areas with both detached homes and apartments with a high proportion of renters. In addition, there might be a link between ownership and the relationship between renters and residential vegetation. Montreal is a city of tenants (average proportion of renters per DA being 66.5%) with a distinctive pattern of housing tenure. Choko and Harris (1990) suggested that a local culture of property ownership in Montreal has emerged in the 1940s due to the stock of multi-unit dwellings, income, ethnicity and class composition. This culture, consisting of social institutions, attitudes and behaviour, is associated with a high rate of tenancy and also probably framed the housing market, arrangements between tenants and landlords and the use of public services in the city (Choko and Harris 1990). Although the tenancy rate nowadays is lower than in the past, the legacies of such mechanisms might still have an impact on the positive association between the proportion of renter and the distribution of vegetation in Montreal. Future research would be necessary to investigate the potential mechanisms explaining this renter-vegetation relationship.

6.3. Effects of borough location

The effect of the administrative borough where a DA was located proved to be influential in all the investigated models. Controlling for the borough location gives us greater confidence in our results associated with the built environment and socio-demographic factors. We were surprised by the negative relationship with the backyard indicators found in Rivière-des-Prairies–Pointe-aux-Trembles (RDP-PAT). We suggest this result may be a historical legacy common in urban areas, such as Montreal, that have grown over time by annexation of previously developed land. The PAT portion was annexed into the City of Montreal in 1982 (Archives of Montreal 2011). Prior to this date, these areas would not have benefited from extensive tree planting efforts by the former City of Montreal and thus might be expected to have differences in tree/shrub cover (Boyce October 24, 2011, Division of Large Park Management, City of Montreal, personal communication). Explaining the significant effects of other boroughs (e.g. Côte-des-Neiges–Notre-Dame-de-Grâce and Ahunstic-Cartierville with positive effects on tree/shrub cover) needs in-depth analysis of past tree planting and tree selection in Montreal boroughs.

In addition, since 2002, boroughs in Montreal have been administrated by a complex political system which includes the City council, borough councils and borough mayors elected from three municipal parties. Depending on political allegiances, themselves often related to local socio-economic, linguistic situations and cultural differences, the management of local services, including those related to the environment, may vary considerably across boroughs (Collin and Robertson 2005). Results of our research suggest that borough differences are important drivers of vegetation cover and should be considered in future urban forestry research. Furthermore, efforts to increase ecosystem services or address inequitable vegetation distributions should also consider the importance of administrative entities with specific geographic jurisdictional boundaries.

7. Conclusion

It is important to mention the possible limitations of this study and to suggest further research. First, the effects of lifestyle on vegetation cover (Grove et al. 2006a) were not directly considered in this study. Introducing separate lifestyle variables may improve the models and shed light on differences such as those between suburbs and urban areas. Second, we focused on the dissemination area as the spatial unit of analysis (containing 400 to 700 people, in average). As underlined by previous authors, the factors influencing urban residential landscapes operate on multiple scales, such as household- and neighbourhood-level formal and informal institutions and municipal-level land-use governance (Chowdhury et al. 2011; Conway et al. 2011). Finally, our research investigated statistical associations between the factors and vegetation cover but qualitative research (e.g. cultural preferences and attitudes towards vegetation planting and management (Larson et al. 2009)) would likely provide the most useful information to understand the causal factors responsible for these associations.

To conclude, our study provides further evidence that the unevenness of urban vegetation cover is affected by a complex range of factors related to the built environment, socio-demographic characteristics and differences in intra-urban administrative hierarchies. More specifically, we show that the built environment, especially population density, is a key factor in limiting the amount of backyard vegetation. Given the trend toward increased urban density, driven for example by a decline in family size and the scarcity of available land (Liu et al. 2003), trade-offs between housing patterns and vegetation cover will be increasingly important decisions in the future that will affect how cities maximize the ecosystem services provided by vegetation. Maintaining green residential areas may require additional investment in management programs targeted at urban residents (Smith et al. 2005; Troy et al. 2007). Furthermore, our results provide additional evidence to suggest that planners and managers who wish to address uneven vegetation distributions may need to customize their efforts for different resident populations such as recent immigrants and less-educated residents.

Regression results also show the street tree/shrub model have a lower explanatory power, unexpected effects of the built environment and fewer significant variables. Predicting street trees/shrubs appears to be more complex than the other indicators, and more efforts are needed to better understand the unevenness of street trees/shrubs. Finally, the significant effects of administrative units (boroughs) in Montreal suggest that difference between intra-urban jurisdictional entities may play an important role in shaping vegetation cover. To be successful, vegetation management strategies to increase ecosystem services and address environmental equity concerns should consider the implications of these built-environment, socio-demographic and administrative jurisdictional factors.

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