UNIVERSITÉ DU QUÉBEC À MONTRÉAL

WHO GROWS FOOD AT HOME? ANALYSIS OF POPULATION CHARACTERISTICS AND RESIDENTIAL URBAN AGRICULTURE IN THE MONTREAL METROPOLITAN COMMUNITY AREA

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QUI CULTIVE LA NOURRITURE À LA MAISON ? ANALYSE DES CARACTÉRISTIQUES DE LA POPULATION ET DE L'AGRICULTURE URBAINE RÉSIDENTIELLE DANS LA RÉGION COMMUNAUTAIRE MÉTROPOLITAINE DE MONTRÉAL

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AUTHOR'S DECLARATION

This dissertation consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

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ABSTRACT

Urban agriculture, a growing form of urban food provisioning in industrialized cities such as Montreal, Toronto, Vancouver and Portland, is estimated to be practiced by 40% of the population. Urban agriculture can take many forms, be applied at various scales, occupy a range of spaces, as well as respond to a diversity of socio-economic and environmental challenges of the 21st century. Urban food gardens have been found to contribute to more than just urban food provisioning, because they also support ecosystem services through the greening of urban spaces. As previous studies evaluating the role and benefits of urban agriculture have focused primarily on community and collective gardens, this study will focus on urban agriculture at the household level, known as residential food gardens, occurring in the back and front yards. To better understand their role at the household level, five territories in the Montreal Metropolitain Community area with contrasting population densities, socio-economic demographics and immigrant groups were selected to examine spatial patterns of food gardens and their socio-economic and ethnocultural determinants, while controlling also for population density. A mixed-model, mapping and spatial analysis were used to determine whether relationships existed between the spatial distribution of residential food gardens and socioeconomic and demographic variables at two spatial levels: across dissemination areas and at the territory level. Results confirmed that residential food gardens were unevenly distributed across the five territories. Homeownership followed by citizens with a Mediterranean-European or Middle-Eastern background had the greatest influence on the number of residential food gardens. Furthermore, testing the random effects within each territory confirmed that income levels and education had varying associations to the number of residential food gardens depedending on the territories. Therefore, this study reveals the variation in population profiles, gardening motivations as well as the needs of urban gardens, confirming the need for further policy and program development at the local (community) level to better support the population interested in or practicing urban gardening.

Keywords : urban agriculture, residential food gardens, socio-demographics, spatial autocorrelation, urban liveability

RÉSUMÉ

L'agriculture urbaine, une forme croissante d'approvisionnement alimentaire urbain, est estimée à être pratiquée par 40 % de la population dans les villes industrialisées telles que Montréal, Toronto, Vancouver et Portland. L'agriculture urbaine peut prendre de nombreuses formes, être appliquée à différentes échelles, occuper une gamme d'espaces, ainsi que répondre à une diversité de défis socio-économiques et environnementaux du XXI siècle. Comme les études précédentes évaluant le rôle et les avantages de l'agriculture urbaine se sont principalement concentrées sur les jardins communautaires et collectifs. Dans ce mémoire, nous nous intéressons à une forme de l'agriculture urbaine, soit les potagers urbain dans les cours arrière et avant. Il a été démontré que les jardins potagers urbains contribuent à plus que l'approvisionnement alimentaire urbain, car ils soutiennent également les services écosystémiques par le biais de l'écologisation des espaces urbains. Cinq territoires de la région de la Communauté métropolitaine de Montréal ayant des densités de population, des données socio-économiques et des groupes d'immigrants contrastés ont été sélectionnés. Un modèle mixte, une cartographie et une analyse spatiale ont été utilisés pour déterminer s'il existait des relations entre la distribution spatiale des jardins potagers résidentiels et les variables socioéconomiques et démographiques à deux niveaux spatiaux : à travers les aires de diffusion et au niveau du territoire. Les résultats ont montré que les jardins potagers résidentiels étaient répartis de façon inégale avec des poches de concentration importantes dans les cinq territoires. Le fait d'être propriétaire suivi par les citoyens d'origine méditerranéenne, européenne ou moyen-orientale a eu les plus grandes associations avec le nombre de jardins potagers résidentiels. De plus, le test des effets aléatoires au sein de chaque territoire a confirmé que les associations du revenu et de la scolarisation avec le nombre de jardins potagers résidentiels varient entre les territoires. Par conséquent, cette étude démontre la variation des profils de population et l'impact sur les motivations de jardinage ainsi que les besoins des jardiners. Nous soulignons la nécessité de développer davantage de politiques et de programmes au niveau local (communautaire) pour mieux soutenir la population intéressée par le jardinage alimentaire ou qui le pratique.

Mots clés : agriculture urbaine, jardins potagers résidentiels, socio-démographie, ethnicité, autocorrélation spatiale

INTRODUCTION

Feeding the worlds growing urban population has gained increasing interest throughout the literature. From land use challenges, urbanization, food security and increasing pressure on environmental resources, the dramatic shift and growth of urban populations will increase pressure on urban systems and the socioeconomic and environmental challenges they currently face. By 2050, the global urban population is forecasted to reach 68% (United Nations 2018). In Canada, 82% of the current population resides in cities (Trading Economics 2020). To meet increasing urban demand and respond to environmental uncertainties, municipalities throughout North America have developed policies and programs targeting sustainable urban development, food security, and climate action (McClintock et al., 2016; See also the City of Toronto, 2020 and City of Vancouver, 2012).

Among those programs, urban agriculture has gained increasing attention for its use as a multifunctional tool that supports the development and evolution of social, environmental, and economic structures of cities (Duchemin et al. 2009), which contribute to their liveability and resilience (Barthel, Parker, and Ernstson 2015; Giles-Corti et al. 2016; Lowe et al. 2019). However, recent studies have observed uneven distribution of food assets such as urban agriculture (Bertrand, Thérien, and Cloutier 2008; McClintock et al. 2016; Smith, Greene, and Silbernagel 2013; Taylor and Lovell 2012). Although there has been extensive scholarship on the benefits and distribution of community and collective gardens or other forms of urban green infrastructure in North America (Pham et al. 2013, 2017; Taylor and Lovell 2012), few studies have explored the role and distribution of gardens at the domestic level (Conway and Brannen 2014; McClintock et al. 2016; Smith et al. 2013). Although, most urban food production takes place at the domestic level, few empirical studies evaluate their production, gardening practices, or motivations (Duchemin and McClintock 2020; Marie 2019; Pourias, Duchemin, and Aubry 2015).

Although studies in the Montreal Metropolitan Community (MMC) area, have examined the presents of food deserts (Apparicio, Cloutier, and Shearmur 2007; Bertrand et al. 2008) and the role and benefits of community and collective gardens (Duchemin et al. 2009), little attention has been completed at the domestic level. Therefore, this study will examine the spatial patterns of residential food gardens in five territories of the MMC area: Terrebonne, Chomedey (City of Laval), Rivières-des-Prairies-Pointe-aux-Trembles, Montréal Nord and Parc-Extension. This study will determine how population profiles can influence the presence and extent of residential food gardens across and within each territory. Examining the five territories within the MMC area will provide a better understanding of the challenges and opportunities of residential food gardens as well as develop a deeper understanding of their role, as a form of urban agriculture. Using spatial mapping and statistical modelling, I examine the spatial patterns of residential food gardens along with their correlation with socio-economic, ethnocultural and urban form variables. Lastly, this study will provide recommendations for urban policymakers on how to further integrate and support residential food gardens within the city.

CHAPTER I

RESEARCH PROBLEM

1.1 Introduction

The following chapter will outline the societal context framing our research problem. It will establish the definition of urban agriculture, and the socio-economic, political and environmental challenges it faces. Lastly, it will outline the research questions as well as the significance of the study.

1.2 Cities, food challenges and the role of urban agriculture

Urban agriculture has seen a dramatic increase throughout North American cities. In Vancouver, Toronto, Montreal (Canada), and Portland (USA), it is estimated that 40% of citizens practice urban agriculture (City Famer 2002; Duchemin 2020; McClintock et al. 2016). Integrating urban agriculture within urban policy and development has been driven as a part of making cities more resilient and liveable in the face of economic and environmental uncertainty as well as for the health and well-being of humans and the environment (Lowe et al. 2019). From home food gardens to large-scale urban farms, urban agriculture is a part of the food system involving the production, processing, transformation, distribution, consumption and waste of food and non-food products (Hui, 2011 cited from Smit et al., 2001). Furthermore, it contributes to the pillars of a what is defined as liveable communities: 'safe, attractive, socially cohesive and inclusive, and environmentally sustainable; with affordable and diverse housing linked by convenient public transport, walking and cycling infrastructure to employment, education, public open space, local shops, health and community services and leisure and cultural opportunities' (Lowe et al. 2015, pg. 138). Although in the Global South, urban agriculture has been highly cited to reduce food insecurity and post-disaster impacts for vulnerable populations (Jehlička, Daněk, and Vávra 2019), a similar phenomenon has been observed in the Global North, especially during the current global health pandemic of COVID19, which has threatened communities' health and financial stability across socio-economic demographics (Clarke et al., 2019; Hobbs 2020).

Aside from its documented role as a provider of fresh food products in proximity to large urban populations, over the last decade, studies have demonstrated that the role of urban agriculture is complex and contributes to many socio-economic challenges of the 21st century; access to fresh and nutritious food in cities, increasing overall vegetable intake and physical activity (Utter, Denny, and Dyson 2016; Gray et al. 2014), job creation (Reynolds 2015), providing greater community cohesion (Daclon-Bouvier, 2001 cited in Duchemin et al. 2009), increases community and individual food self-sufficiency and social empowerment (Grewal and Grewal 2012; MacRae et al. 2010) as well as encouraging greater social-wellbeing and mental health (Darby et al., 2020; Pollard et al. 2018). As illustrated in Figure 1.1, Duchemin et al. (2009) discuss the multiple benefits of urban agriculture that contribute to the sustainable development of cities, and demonstrates that the role of urban agriculture goes well beyond the production of food. Yet, urban agriculture can confront a host of challenges resulting from the limited space in urban areas (physical), policies, by-laws and regulations (political), social acceptance of urban agricultural projects and financial means for start-up and maintenance costs (socio-economic) as well as environmental constraints such as heat, urban pollution and soil contamination.

Figure 1.1 Multifunctionality of urban agriculture as illustrated in Duchemin et al. (2009)

1.3 Definitions of urban agriculture

Urban agriculture can be broadly defined as the production of food and non-food products within (*intra*) or around (*peri*) cities (Lin, Philpott, and Jha 2015; Mougeot 2006; Siegner, Sowerwine, and Acey 2018; Taylor and Lovell 2012). Although this definition focuses solely on the food production aspect of urban agriculture, research continues to expand its role by supporting the economic and social development of cities as well as contributing to urban biodiversity and habitat by occupying underutilized spaces, including parks, vacant lots, rooftops and alley-ways.

As urban agriculture continues to become better integrated within cities, such as in school and community programs, they act as learning centers throughout the urban landscape, holding knowledge, innovation and experimentation as their form and structure are annually altered as people and communities learn and relearn how to best manage these growing spaces (Barthel et al. 2014). Therefore, urban agriculture can be defined as plots of innovation of varying sizes and structures located in cities, which contribute to the food and non-food products produced in proximity to citizens. They are essential elements of the local food system that contribute to urban food self-sufficiency and provide learning and knowledge-sharing opportunities for citizens.

1.3.1 Types of urban agriculture and physical constraints

The physical constraints of urban agriculture could be associated with a city's urban form, or otherwise known as its physical characteristics such as housing type and its spatial distribution throughout the city (Živković 2020). Depending on the type and scale of urban agricultural projects, the urban form can significantly influence the role of urban agriculture. For example, in cities with high population density, the concentration of high-rise or multi-level buildings can result in urban agriculture occupying balconies and rooftops. For individuals limited to balcony space, this can significantly reduce their productivity potential (quantity and types of produce grown), as the available space as well as urban microclimates (urban heat and pollution) provide harsher growing conditions (Hui 2011). Roof-top gardens have the potential to occupy large underutilized urban spaces. However, they can face maintenance challenges and security concerns. For example, materials such as plants and soil would need to be brought up to the rooftop; as the weight of balcony or rooftop gardens needs to be taken into consideration, especially in northern communities, where annual snowfall and precipitation increases the total weight of garden pots, bins or other infrastructure holding garden beds (Meletis 1998). Furthermore, high-density city-centers may not be suited for animal husbandry due to sanitation restrictions, space and animal welfare concerns (Gravel and Vermette 2019).

Lastly, land-use composition and distribution of green-spaces, parks, and access to these areas through bike-lanes, side-walks and public transportation, can limit who has access to urban agricultural projects. However, unlike other forms of urban agriculture, residential food gardens provide direct access to fresh fruits and vegetables, thus increasing the food security within cities by increasing the access to food: the quality, freshness and variety (organic versus non-organic) as well as diversity of food products (see Kortright and Wakefield 2011, pg. 13). Therefore, cities' physical structure and their walkability can greatly affect who has access to urban agricultural projects in and around their residence.

1.3.2 Urban agriculture and environmental challenges

Access to fertile soil, light and precipitation is crucial for the growth and harvest of food and non-food products (except for aquaponics and other forms of indoor urban agriculture). Although under-utilized spaces such as vacant lots can be an opportunity for urban agricultural projects, health concerns caused by environmental hazards such as heavy metal contamination in the soil can alter the type of urban agriculture practiced and the materials required. For example, sites with soil contamination would require decontamination, otherwise garden beds would need to be built above ground, adding a significant cost to urban agricultural projects. Physical and biological soil remediation techniques exist to extract hazardous contaminants from soil (Brown and Jameton 2000). Physical remediation techniques include excavation, geotextiles, soil washing and soil vapour while biological remediation includes: microbial remediation, phytoremediation, fungal remediation and compost remediation (refer to Heinegg et al. 2002). However, the cost associated with soil remediation can depend on variables such as the size of the site, the type and level of soil contaminants as well as the land-use post-remediation (Heinegg et al. 2002). Although soil remediation programs do exist for boroughs in the City of Montreal, they are geared to the redevelopment of land and do not currently consider urban agricultural projects (Ville de Montreal 2019). Furthemore, the soil contamination level for agricultural use is the most strict (Heinegg et al. 2002). Therefore, more research is needed to fully understand the uptake of heavy metals and toxins in various crops and their effect on human health (Lovell 2010) as well as alternative urban agricultural gardening practices for contaminated sites.

As precipitation and temperature changes are anticipated with global climate change, urban agriculture, like other forms of agriculture are at risks to damage of frequent and severe storm events, heat stress caused by urban heat island effect, and changes in seasonal temperatures, including variation in thaws and freezing, as well as the presence and severity of pests and disease (Dixon et al. 2009; Howden et al. 2007). Ouranos, a non-for-profit organization developing and coordinating projects related to climate adaptation has developed climate variability models illustrating the variation of temperature, precipitation, thaws and freezing under two greenhouse gas emission scenarios (*https://www.ouranos.ca/climate-portraits/#/regions/28*). Although maps of the climate impacts can be viewed on their webpage, further research is required to outline the adaptations needed for citizens and entrepreneurs operating urban agricultural projects.

Lastly, it should also be acknowledged that not all crops are suited to urban environnements. Although research is beginning to evaluate the potential of crops such as wheat in urban environnments (Asseng et al., 2020), more research is needed to confirm the success and yields of these crops.

1.3.3 Urban agriculture, impacts of policy and social acceptability

On the island of Montreal, land competition and restrictions on land use can limit the presence and type of urban agricultural projects: zoning by-laws, health and animal husbandry regulations often restrict the raising of farm animals in cities (Gravel and Vermette 2019; McClintock 2014). For example, in the City of Montreal, urban chickens have often been disputed for human health and animal welfare concerns (Gravel and Vermette 2019). However, they have been increasingly accepted throughout the MMC area, as a part of community gardens for educational purposes (Gravel and Vermette 2019; Ville de Montreal 2017). For citizens wishing to acquire urban chickens, they must consult the boroughs webpage (*Poules en milieu urbain*) and contact the Laboratoire sur l'agriculture urbaine.

Another example on the island of Montreal is the introduction of eco-grazing in Montreal's Botanical Gardens. In collaboration with the Laboratoire sur l'agriculture urbaine (AU/LAB), "Biquette à Montreal", an eco-grazing project using a heard of sheep is shepherd across the park to manage its green spaces (Ville de Montreal 2018). Not only do the sheep provide a more eco-friendly way to maintain the parks grass areas, but provide a point of interest for visitors as well as an educational opportunity. Integrating sheep within Montreal's urban sector required educational campaigning and approval from both the borough of Rosemont-La Petite Patrie and the City of Montreal for the grazing of sheep in the urban zone (Le Laboratoire sur l'agriculture urbaine 2020).

In Berlin, Germany, a recent study evaluating the factors that could affect the social acceptability of urban agricultural projects, and therefore their success or failure, found that there was a low social acceptance for urban agricultural project integrating urban animal production (pg. 17) (Specht et al. 2016). Some of the reasons associated with the low-acceptance levels were due to the perceived 'unnatural' environment of cities, decreasing the quality of life for farm animals with increased noise and odours (Specht et al. 2016). Although this perspective could vary on the type, scale and location of an urban agricultural project, animal welfare is one of the greatest influences of urban animal agriculture (Gravel and Vermette 2019; McClintock, Pallana, and Wooten 2014; Specht et al. 2016). Therefore, urban animal production could face many barriers, as laws, regulations and social acceptability of urban agricultural farming pose many constraints.

Lastly, few articles discussed the challenges of odours and pests that urban agriculture can attract from unmanaged gardens or composts, they can also affect the social acceptability of urban agriculture projects. In Specht et al.'s (2016) study, participants in Berlin, Germany indicated that urban agricultural projects could lead to "increased noise, dirt and odours" (pg. 9). Although the attraction of pests was not specifically mentioned, urban chickens, unmanaged composts and gardens can attract urban pests such as rats, raccoons, squirrels and possums. As the production of food has been pushed to the outskirts of city limits, reintegrating food production in proximity to a large urban population requires education on gardening, harvesting, animal welfare and management as well as composting to ensure the maintenance and quality of garden-beds, and reduce the prevalence of urban pests such as rats and raccoons as well as to avoid any health risks. Further research is needed to evaluate urban agriculture and the pests it can attract as well as the influence of social acceptability on the establishment of urban agricultural projects.

1.4 Economic and social benefits of urban agriculture

Residential food gardens, amongst other forms of urban agriculture, provide a multitude of social, economic, and ecological benefits for individuals and communities. Although residential food gardens represent a ubiquitous and under-researched form of urban food production (McClintock et al. 2016), its presence in front, backyards, and balconies of residential spaces provide citizens with the opportunity to grow a portion of their food supply (Pourias et al., 2020; Smith et al., 2013; Wise, 2014).

Economic benefits

Economic constraints can vary depending on the type and scale of urban agricultural projects. For large urban farms, access to large spaces and labour costs can cause significant limitations. Although increasing individual food self-sufficiency can reduce annual grocery expenditures, annual harvest yield can vary depending on the geographical location (Nogeire-McRae et al. 2018). Furthermore, residential food gardens can provide annual food savings, however, this can depend on the cost of inputs (organic versus non-organic food products, see Table 2 on page 753 Nogeire-McRae et al. (2018)). As food self-sufficiency refers to the ability of an individual, community or country to provision all food and non-food products required for a healthy and sustainable diet, today complete food self-sufficiently is not always viable due to environmental conditions such as climate, diet, and available growing space in proximity to urban populations. Therefore, urban agriculture can contribute to increasing urban food production, stimulating local economies through the creation of new jobs and reducing the overall ecological footprint of the food system (food production, processing, transportation, distribution and consumption) (Altieri et al. 1999; Duchemin et al. 2009; Haberman et al. 2014).

Furthermore, producing food locally and directly in cities will become increasingly important as the resources needed to feed a growing urban population extends well beyond city limits (Deelstra and Girardet 2000). Therefore, re-localizing food production can have positive economic benefits, encourage greater food self-sufficiency and mitigate impacts from unprecedented global disruptions such as the global COVID19 health pandemic (Clapp 2017; Hobbs 2020). Results from a recent survey in the MMC area demonstrated that 45% of participants practiced urban agriculture, with 20% motivated by the current pandemic conditions (Duchemin 2020) urban agriculture in all forms provides important and direct access to food. However, access to space is a limiting factor in cities, and for those earning less than $20,000-

$40,000 annually, income level can significantly reduce their access to housing with front or back yards (Duchemin 2020). Lastly, urban agriculture's economic benefits remain to be a gap throughout the literature and, thus, require further empirical research.

Social benefits

Growing food directly in front or backyard gardens has shown to have many positive impacts on an individual's physical and mental health (Darby et al., 2020; Pollard et al., 2018). As gardeners spend more time outdoors and often share knowledge and produce with neighbours, family members, and friends (Darby et al., 2020). Increasing social connections and building social networks in neighbourhoods promotes greater community cohesion and knowledge-rich food networks of gardeners with various gardening practices, plant varieties, harvesting, and processing techniques (Darby et al., 2020). Learning and sharing knowledge concerning the growing, processing, and cooking of food contributes to what Barthel and Isendahl, (2013) define as "social-ecological memories." That is the safeguarding of knowledge and the continued learning of food production and consumption over time that contribute to the resilience of food production as well as urban food security. Other positive impacts of residential food gardens include greater access to fresh produce, as well as food that meets dietary or cultural food preferences.

1.5 Urban agriculture in the Montreal Metropolitain Community area

1.5.1 History of urban agriculture

Gardening in Montreal's metropolitan area has existed for decades (Cultive ta Ville, 2020; Bhatt and Farah, 2016) and the City is now considered as a leader in urban agriculture in North America (Bhatt and Farah, 2016). Shaped by population migrations, economic and global food crises, urban agriculture has become an integral part of Montreal's urban landscape (Cultive ta Ville, 2020; Bhatt and Farah, 2016).

In the past, as "urban agriculture combines agricultural issues with those related to urban development" (Duchemin et al., 2009), industrialization and urbanization have pushed agricultural activities to the border of city limits. However, in cities like Montreal, there has been an increasing number of urban agricultural projects in the inner city. Since 1974, when the first community garden was established on the island of Montreal, the movement continued to grow, and in 1985, 43 community gardens were established to meet increasing demand (Duchemin et al., 2009). Today, there are an estimated 1187 urban agricultural projects throughout the city: 111 community gardens, 157 collective gardens, 426 residential gardens, three rooftop gardens (although this only includes commercial producers) and 36 urban farms (Bernier and Duchemin 2020). Although, the number of urban agricultural projects identified by "Cultive ta Ville" provides only an estimate of the total number of urban agricultural initiatives and projects, as they must be registered by the individual or business to be identified on the map. All in all, research and current mapping of urban agricultural projects in Montreal confirm their presence throughout the city.

Previous studies examining the motivation of individuals and communities participating in urban agriculture in Montreal have had varied results. In Bouvier-Daclon & Sénécal's (2001) study, they found that 20% and 55% of individuals participating in collective gardens earned below $20,000 annually, showcasing the role of urban agriculture as financial support for those earning modest to low-incomes and facing food insecurity. Furthermore, community and collective gardens have demonstrated to produce between 7 kg and 28kg of fresh vegetables per person (Duchemin et al., 2009) or 2.5 kg/m^2 (Duchemin and McClintock 2020) (with the variation primarily due to growing conditions, practices, knowledge and types of plants grown). Furthermore, studies have shown that producing food is the primary motivation of gardeners, followed by the quality of food produced, and potential economic savings (Pourias, Aubry, and Duchemin 2016).

In response to the growing interest in urban agriculture within the City of Montreal, the Department of Sustainable Development (although this department no longer exists) conducted a survey in 2013 to discern the number of citizens currently participating in urban agricultural activities. Based on this survey, 42% of citizens on the island of Montreal confirmed they practiced urban agriculture (Ville de Montreal, 2013), however, this included individuals with potted plants on balconies, which can vary in production yield in comparison to garden plots or raised beds. Most importantly, 63% of respondents confirmed they practiced urban agriculture in their backyard. Other forms of urban agriculture included balcony gardens (34% and 43% in the city center), community gardens (8% and 12% in the city center), gardens in front yards (4%), and rooftop gardens (1%) (Ville de Montreal, 2013). With urban front and backyard gardening representing the greatest percentage of urban agriculture in the City of Montreal, the survey confirmed the importance of residential food gardens, and the need to better understand the motivations and the influencing factors that could affect their distribution. Although recent research has begun to identify residential food gardens (Laboratoire sur l'agriculture urbaine (2020) that identified 426 residential food gardens), few studies have mapped and analyzed the distribution of residential food gardens across the MMC area.

1.5.2 Public policy that supports urban agriculture and the local food system

Since the integration of Montreal's community gardening program in 1975 (Bhatt and Farah, 2016), urban agriculture has also become further integrated within Montreal's urban policy and development programs. For example, the development plan of Montreal (2014) integrates urban agriculture within the city's greening actions and urban green infrastructure (section 3.6 A green city (Ville de Montreal, 2014). Urban agriculture will be a primary element within these plans as they provide direct access to fresh food products in cities. Furthermore, Montreal's Sustainable Development Plan 2016-2020 includes two actions geared towards better integration of urban agriculture as a part of the health and sustainability of the city. Specifically, Action 12 of Montreal's Sustainable Development Plan, which outlines that urban agriculture will be integrated as a part of the development and design of neighbourhoods to support healthy lifestyles (Montreal 2016). Furthermore, Action 15 aims to support access to a healthy diet and to urban agricultural activities. Both actions serve to better recognize the role of urban agriculture in supporting urban health. More recently, however, Québec's ministry of agriculture (Le ministre de l'Agriculture, des Pêcheries et de l'Alimentation de Québec (MAPAQ)) recently published an announcement for municipalities and native reserves across the province to submit an action plan for the development of more food self-sufficient communities (Plan de développement de communautés nourricièeres (PDCN)) (MAPAQ 2020).

Furthermore, the City of Montreal's public policies and urban development strategies that have supported the growth and development of urban agricultural projects have been manifesting for decades (Martorell 2017). Since 2011 the action plan for a sustainable and just food system of the Montreal Community (or otherwise known as the SAM – standing for *Système alimentaire montréalais*), has formed to ensure strong leadership in developing a sustainable food system for the City of Montreal through informing and advising decision-makers on food policy and initiatives (SAM n.d.). With their mission and vision geared towards supporting food that is healthy, diversified, affordable and in proximity to individuals across the city (SAM n.d.), it was officially announced as Montreal's first Food Policy Council in 2018. In accordance with urban agriculture, the SAM held several forums and workshops identifying the constraints and gaps in Montreal's food system, including an annual conference dedicated to urban agricultural producers to exchange information concerning best practices, as well as for those looking to start educating gardeners as a part of school programs (SAM n.d.). Although these initiatives are essential for the development of Montreal's local food system, they are geared towards entrepreneurs, businesses, grass-root organizations and municipal decision-makers. Lastly, in november 2011, a petition with 29 068 signatures demanded that a public consultation be held on the state of urban agriculture in Montreal (OCPM n.d.). Since december 14th, 2020, The Public Consultation Office of Montreal (Office de Consultation Publique de Montreal (OCPM)) was mandated to hold the public consultations. Although documents will be uploaded to the OCPM website, further public consultation will be completed in 2021.

At the municipal level, Québec's ministry agriculture (Le Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec) developed a strategy to support urban agriculture 2016-2019 (Gouvernement du Québec, 2016), which encourages municipalities to develop urban agricultural strategies (Plan d'agriculture urban). Since then, two territories have developed policies to integrate urban agriculture within their planning and development: Rivières-des-Prairies Pointe-aux-Trembles (RDP-PAT) and the City of Longueuil. In an effort to improve the quality of life of urban citizens RDP-PAT recently adopted their PAU (PAU – *Politque d'agriculture urbaine*) in december of 2019 with a vision to devote 30 hectares to urban agricultural projects by 2030 (Arrondissement de Rivière-des-Prairie-Pointe-aux-Trembles 2019). The policy recognizes the multi-dimensional role of urban agriculture and identifies five guiding principles on how it will support the development and growth of urban agriculture over the next decade. Although this policy provides the first step in the support and development of urban agriculture across the territory, there remains a significant amount of research for the identification of space, financing projects and well the management and care in the long-term. For the City of Longueuil (2020), their urban agricultural plan better defines urban agricultre within its territory dividing into three categories: private, participative, and commercial. It then identifies the current challenges and gaps as well as provides an action plan around the three orientations.

Territories such as RDP-PAT have integrated PAU's (Plan d'agriculture urbaine) to envision how urban agriculture can be further integrated within the territory (Arrondissement de Rivière-des-Prairie-Pointe-aux-Trembles 2019). By providing a definition of urban agriculture, and clearly identifying where urban agricultural projects can be located to meet the needs of citizens, policy and decision-makers are better able to identify opportunities and constraints for urban agriculture projects as well as integrate them through strategic planning.

1.6 Aim and research questions

Changing climate and the fragility of the global food system, especially during the current global health pandemic, has highlighted the need to evaluate urban food production capacity, more specifically who grows food and why. Residential food gardens, like community gardens are spaces managed by people, and can be used as spaces to grow food, to host gatherings, culture amongst other functions (Campbell 2016). They have also been shown to support both community's needs in fresh food (Darby et al., 2020) and environmental health (Lin et al., 2015) and are an essential component to curent and future urban planning (McClintock et al., 2016). Therefore, residential food gardens contribute to the landscape of urban agricultural throughout cities, and provide citizens with direct access to fresh fruits and vegetables. With little research focused on residential food gardens, identifying whether they are accessible throughout the MMC area, as well as how they contribute to urban food security and resilience, can be utilized to better develop urban food policy and food programs.

The most common form of residential food gardens include garden plots, raised beds and pots (Figure 1.2). For this study, residential food gardens focus on the presence of garden plots and raised beds as they can be identified using satellite imagery.

Figure 1.2 Types of residential food gardens (*images were taken from Google images and altered in Photoshop)

More specifically, the study aims to better understand the socio-spatial dynamics of residential food gardens in the MMC area to identify the socio-economic and ethnocultural variables that have the greatest influence on the presence and extent of residential food gardens. Therefore, this study will explore the following two research questions:

Question 1 : What are the extent and spatial patterns of residential food gardens in five territories of the Montreal's Metropolitan Community area?

Question 2: How are population profiles associated with the prevalence of residential food gardens and how do the population profiles' associations vary across and within the five territories?

1.7 Project significance

Analyzing the relationships between the spatial distribution of residential food gardens and population profiles enables city planners and professionals working in the health sector, social services, urban planning, and sustainability combat the socio-economic challenges of the 21st century (Giles-Corti et al., 2016). In the context of emergency risk assessment for the resilience and stability of urban populations to withstand disruption stemming from economic market crashes, environmental catastrophes or global pandemics, the capacity at which populations can provision and meet local food demands is crucial (Hamin and Gurran, 2009). The Cuban context is a common example used to demonstrated the use of urban agriculture as a food provisioning tool in response to disruption in food distribution (Darby et al., 2020).

The interest of this study is to better understand socio-economic factors influencing their presence as well as a how their size and distribution differentiate under varying population profiles and urban form characteristics. In comparison to other recent studies focusing on residential food gardens (Gray et al., 2014; Kirkpatrick & Davison, 2018; McClintock et al., 2016; Smith et al., 2005), few comparisons between urban and suburban communities have been completed. Therefore, this study underlines the importance of undertaking research in socially and physically diverse areas, and working at a fine spatial scale to integrate urban agriculture and other forms of urban green infrastructure to meet the needs of individuals and communities.

1.8 Summary

In this chapter, I lay out the societal context of urban agriculture and residential food gardens. Residential food gardens, like other forms of urban agriculture, can have multiple social, economic, and environmental benefits. Although public policy at multiple levels has been promoting urban agriculture, there is still scant research on residential food gardens in the province of Québec and in Montreal in particular. Examining the influence of socio-economic, urban form, and ethnocultural factors is important, since it could help explain the distribution of residential food gardens as well as identify vulnerabilities or needs for future programs and policy. In the next chapter, I explain how I conceptualize residential food gardens in a conceptual framework.

CHAPTER II

CONCEPTUAL FRAMEWORK

2.1 Introduction

The following chapter will discuss the broad socio-political processes that influence the presence of urban agricultural activities across the MMC area. From food policy to the presence, services and resources offered by local food hubs, these socio-political structures can support and encourage urban agriculture and the development of local and sustainable food systems (Blay-Palmer et al. 2013). Furthermore, using literature from North America, Europe and Australian cities, I will also discuss how population density, socio-economic and ethnocultural variables operating at the territory level can influence the presence of residential food gardens across the five territories within this study. Therefore, the following will structure the conceptual framework used to develop the research question as well as support the variables utilized in the statistical and spatial analysis of residential food gardens.

2.2 Broad socio-political processes shaping urban agriculture

To develop sustainable food systems, research has shown that increasing the connections between food system components (production to consumption and post-consumption) throughout cities fosters more resilient and healthy communities (Blay-Palmer et al. 2013).

Food policy and food hubs are two key socio-political elements that support the presence of urban agricultural activities in industrialized cities; as they form the regulatory framework, resources and services needed to support local food system components (production, procession, transportation, consumption and post-consumption) (Blay-Palmer et al. 2013; Duncan et al. 2018; Vivre en Ville n.d.). However, as population profiles can vary across territories and differ in their socio-political and economic needs (which are shaped by the culture, lifestyle, income-levels, health, age, education of each territory), food planning and the location and presence of food-related services can be socio-spatially distributed, creating uneven clustering of food system components such as urban agriculture (production) throughout cities (McClintock et al. 2016).

The following will discuss the influence of food policy and food hubs and how they contribute to the local food system and socio-spatial unevenness of food system components. Lastly, I will discuss how population profiles at the territory level can influence the presence of urban agriculture as well as their use in the spatial and statistical analysis of this study.

2.2.1 Impacts of food policy and movements

The growth and development of food policy in Canada has evolved significantly over the past decade. Since 2001, Food Secure Canada, a pan-Canadian alliance organization working on challenges of food security and food sovereignty through three interlocking goals: zero hunger, healthy and safe and a sustainable food system (Food Secure Canada n.d.). Food Secure Canada has been a crucial stakeholder in pushing for a national food policy in Canada. In 2017, Canada announced its adoption of a national food policy and has since launched several visionary initiatives to address food system priorities for the next few years (2019-2024) (Agriculture and Agri-Food Canada n.d.). The initiatives target the federal level and range from challenges of food waste, poverty reduction strategies, nutrition and healthy eating, economic growth and climate change, as well as sustainable development strategies. Although these challenges are broad, they showcase the diversity and cross-dimensional impact of food system challenges.

As a part of Canada's Budget Plan 2019 (*https://www.budget.gc.ca/2019/home-accueil-en.html*), chapter 4 introduced a Food Policy for Canada as part of its mandate for the health and well-being of Canadians. Over the next five years, 50$ million dollars will be allocated to a Local Food Infrastructure Fund, which includes food banks, farmers markets and other community-driven projects (Figure 4.3 of Chapter 4, part 1). Although urban agriculture, moreover domestic food gardens were not directly mentioned as a part of the strategy, the integration of a national food policy will increase the awareness of food issues and their interrelated role in the anthropogenic and ecological health of cities. As briefly mentioned in Food Secure Canada's food policy proposal:

> "A national food policy should encourage a diversity of agricultural practices and scales, not only industrial-scale commodity production for export. This includes expanded support for food production for domestic and local markets as well as small-scale, ecological production systems and investments that defend people's ability to access land control over productive resources" (Food Secure Canada, 2017, pg. 15).

In Thibert's (2012) study, interviews revealed that urban agriculture is a pivotal educational tool used to increase awareness about food systems and food-related challenges. Furthermore, as the climate crisis continues to threaten urban sustainability, urban agriculture has gained increasing attention as a tool to mitigate food insecurity among other socio-political and economic challenges, demonstrating its role as a multi-dimension tool to support the sustainability and resilience of cities (Duchemin et al. 2009). Furthermore, its integration within urban policy is complex and can include sustainability and action plans, zoning by-laws (permission for urban chickens), food charters (such as the City of Hamilton's Food Charter) as well as health and safety regulations (gate sales). In Soderholm's (2015) study on *Planning for Urban Agriculture in Canadian Cities*, she provides an overview of Canadian cities integrating urban agriculture within urban planning and development strategies for sustainability and resilience (i.e. the City of Ottawa), zoning by-laws (i.e. the City of Montreal) and food system assessment and action plans (i.e. the City of Calgary).

Apart from food policy, urban agriculture can be integrated through other actions and grass-root-based initiatives including: Continuous Productive Urban Landscapes (CPULs) a theoretical concept proposed in academic literature (Viljoen and Bohn 2009), edible landscaping and guerrilla gardening. For example, CPULs advocate the transformation of open spaces throughout cities as a series of productive growing spaces (Viljoen and Bohn 2009). Grass-root initiatives such as edible landscapes also contribute to the burgeoning of urban agriculture across European and North American cities. A common examples include the presence of guerrilla gardens, such as in the City of Vancouver (Zussman 2013) where residents took to cleaning-up at a local park, or in the City of Montreal, where a group of citizens planted over 100 sunflowers throughout the Gay Village of Montreal (Steuter-Martin 2017), and lastly, the well-known city of Todmordern, where two women started planting and harvesting food in the cities unused spaces (Larsson 2018). Now known as Incredible Edible Todmorden (IET), the group has catalyzed a growing global movement of urban gardeners taking over unused city spaces.

2.2.2 Impacts of food hubs: facilitating and supporting urban agriculture

Throughout the MMC area, there are a host of non-for-profits, government services and grass-root initiatives supporting urban agricultural activities throughout the city. Food hubs can be defined as:

> *" networks and intersections of grassroots, community-based organisations and individualks that work together to build increasingly socially just, econmically robust and ecologically sound food systems that connect farmers with consumers as directly as possible"* (Blay-Palmer et al. 2013, pg. 524).

Thus, food hubs offer points of connection within the local food system and provide services and resources that reflect the communities they serve. As illustrated in Figure 2.1, Vivre en Ville, a non-governmental organization (NGO), provides an illustration of a local food hub, offering an array of resources and services to local citizens: community kitchen, collective garden, composting, as well as a local market.

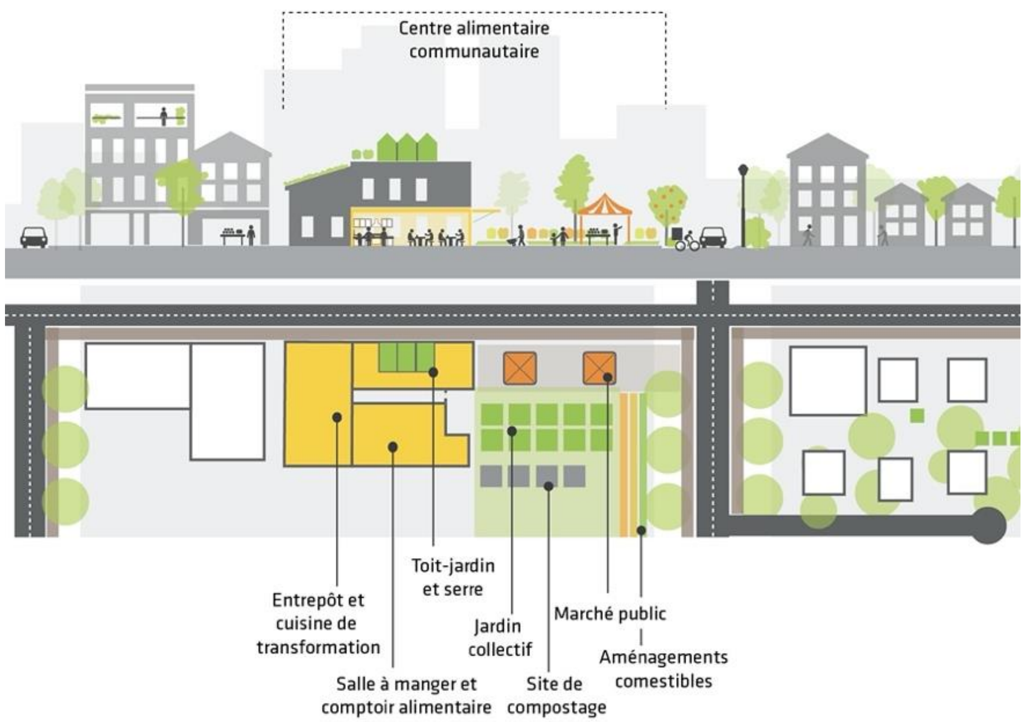


Figure 2.1 Creation of local food hubs in proximity to urban populations facilitates local food economies (Vivre en Ville n.d.)

In Montreal, local food hubs include organizations such as Santropol Roulant, located on the Plateau-Mont-Royal, NDG transition and Le Dépot (located in Notre-Dame-Grace), or Quartier Nouricier, located in Centre-Sud. Furthermore, food hubs can provide the opportunity to rent out or borrow tools, enabling gardeners to tend to and process harvested goods. For example, at Santropol Roulant, canning equipment, as well as the certified kitchen itself, can be rented or booked for communities and individuals wishing to process their summer harvest. Other resources for urban gardeners in Montreal are community composting programs, collecting urban food wastes and turning them into nutrient-rich compost for individual and community gardens. For example, the Grand Potager located on Montreal south-shore bordering the St-Laurent River occupies municipal greenhouses and offers annual seedling, composting and gardening events throughout the year. Their mission is to support social change and food security through urban agriculture by increasing environmental awareness (Grand Potager n.d.). In addition, Mayor Valerie-Plante has mandated that the Botanical Gardens will convert one hector of its property into urban food gardens to sustain 100 people for an entire year while also offering workshops to encourage and help citizens learn gardening skills (Olson 2020).

Apart from NGOs and community organizations, municipalities also support urban gardeners through donations of urban compost (TC Media 2013; Ville de Montreal 2020). Although there are several of organizations, municipal programs and community initiatives that support urban agriculture, further research is needed to examine whether these assets are adequately accessible for citizens of all demographics and that they offer services custom to the socio-economic circumstances of each community.

Therefore, food hubs are essential services for supporting local food system components at the community and domestic level, as they act as social safety nets for individuals who may not have access to these services, knowledge or equipment.

However, as we move from territories located on the island of Montreal to its off-island suburbs, there is a significant decrease in the diversity and number of urban agricultural projects and food hubs available to individuals and community gardeners (Laboratoire sur l'agriculture urbaine, 2020, consulted Montreal's map of urban agricultural initiatives and projects). In a city where the wait-list for a community garden plot can be upwards of two years (Olson 2020), it is essential that communities provide a diversity of spaces, services and outlets to meet the needs of communities. Food hubs are hence of the means that we can use to relocalize the food systems.

Relocalizing the food system has been identified as a strategy to increase local food self-sufficiency, encourage the development of local economies and reduce the ecological footprint of the food system (Campbell 2016; Horst and Gaolach 2015). Although the area of a local food system is highly debated (Campbell 2016), the location and frequency of local food system components (see Figure 2.2) along with the services that facilitate these components (including food hubs, as discussed in the previous section), are unevenly distributed in (post)industrialized cities and in consequence contribute to the presents of urban food deserts. For example, studies evaluating the presence of food deserts, "where access to fresh produce is limited due to reduced proximity to markets, financial constraints, or inadequate transportation" (Lin et al. 2015, pg. 190) have been completed in cities such as in the City of Montreal (Apparicio et al. 2007; Bertrand et al. 2008), where food desert have limited existance or in the rural Minnesotan communities (USA) (Hendrickson, Smith, and Eikenberry 2006). Both studies confirmed inadequate access to local food system components, inhibiting the capacity of citizens and communities to participate in their local food system. Although residential food gardens amongst other forms of urban agriculture can provide local food and reduce food deserts in some neighbourhoods, they are only part of the solution to creating a more sustainable and resilient local food system.

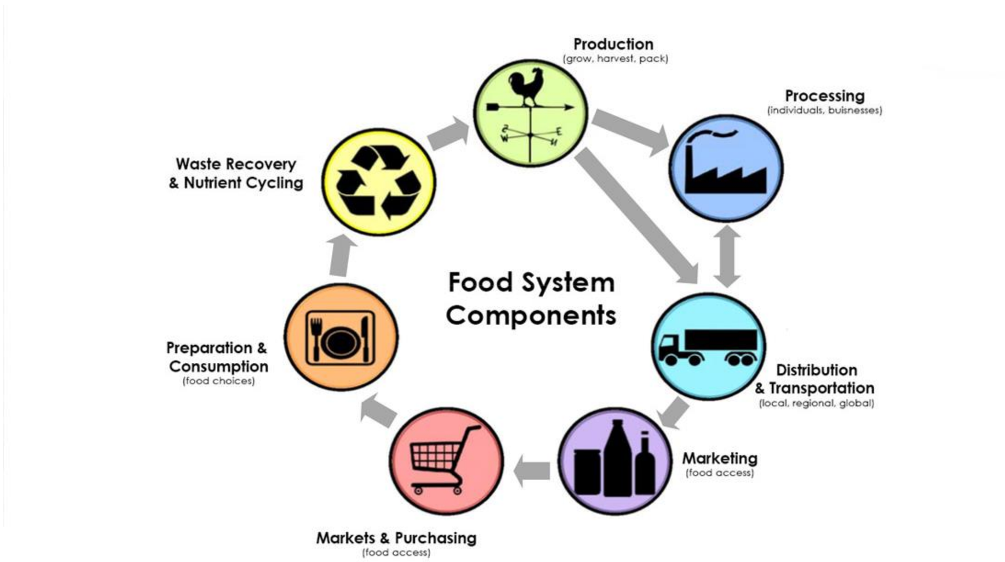


Figure 2.2 Food system components adapted from the University of Idaho (2020).

2.2.3. Other factors that influence the uneven distribution of local food systems

The development of a local food system is a part of the broader socio-political processes that influences the presence, scale and type of urban agriculture in cities. As urban agriculture refers to the production of food and non-food products within the urban zone and contributes to the socio-economic and environmental health and development of cities (see chapter 1 for the definition) (Lin et al. 2015; Mougeot 2006; Siegner et al. 2018; Taylor and Lovell 2012), the location of food system components can directly influence their capacity to feed and meet consumer demands. Thus, as illustrated in figure 2.2, although residential food gardens can help localize the production of food in cities, however, processing and transformation (such as community certified kitchens) of local food products requires the development of infrastructure and policy at the community and city scale to foster their development.

Recent publications have acknowledged the uneven distribution of urban agricultural activities in cities such as Baltimore (MD) (Clarke et al. 2019), Detroit (MI) (Meerow

& Newell, 2017), Portland (OR) (McClintock et al. 2016), Madison (WI) (Smith et al., 2013) and Chicago (IL) (Taylor and Lovell 2012). In relation to the local food system, the uneven distribution of local food system components, such as urban agricultural activities demonstrate that socio-economic processes that can affect the distribution of urban agricultural activities. Therefore, it is important for policy and decision-makers, to validate the factors causing spatial clustering of these resources to ensure that food systen components are equitably acessible across socio-economic demographics.

The uneven distribution of residential food gardens follows similar trends observed in other forms of urban vegetation and gardens, such as urban street trees or canopy cover in the City of Montreal (QC) (Pham et al., 2017 also see Pham et al., 2012 for disparities in urban vegetation) and in Toronto (ON) (Conway, Shakeel, and Atallah 2011). For example, African-American neighbourhoods in Milwaukee (WI) were found to have lower tree canopy cover (Heynen, Perkins, and Roy 2006), while in the City of Montreal, the street tree cover was found to be lower in low-income communities (Pham et al. 2017). Such discrepancy in the access to green spaces is termed as environmental inequity (Heynen et al. 2006; Pham et al. 2012), which has been shown to affect those living under the poverty and marginalized groups, such as visible minorities, Afro-Americans (Heynen et al. 2006; Taylor and Lovell 2015).

Even in circumstances where lower-income communities begin to develop urban green spaces such as parks or community gardens, gentrification, the processes by which the greening of communities increases the economic value of housing and local infrastructure and in consequence, can potentially displace low-income communities (Horst, McClintock & Hoey, 2017). More specifically, although gentrification can increase the services available to local communities, the greening and development of these neighbourhoods also push the communities it serves further from the resources it needs (Horst, McClintock & Hoey, 2017). This thesis was not intended to discuss process, benefits and constraints of urban gentrification, we are aware that it is an important element that contributes to the continued uneven distribution of environmental assets throughout cities.Without equitable access to urban green infrastructure, such as parks, green spaces or urban agriculture, individuals and communities do not have the same access to resources and services needed for their overall wellbeing and quality of life (Conway et al. 2011; Heynen et al. 2006; McClintock et al. 2016; Pham et al. 2017). Therefore, identifying the socio-economic, environmental, ethnocultural, or political variables attributed to their distribution is essential to identify neighbourhoods at greater risk to systemic shocks. Multiple variables contribute to such uneven distribution of green spaces in general and gardens in particular, to what I am turning in the next section.

In summary, the case of Montreal reflects the general trends of promoting urban agriculture in municipal public policy. At the local level, cities across North America have integrated urban agriculture through policy and programs (refer to Chapter 1). In relation to residential food gardens, cities such as Montreal are at the beginning of integrating food policy, and as the focus of these broad socio-political processes act primarily at the federal level, there is an increasing push for municipalities to develop strategic plans outlining their local food system components and the services and resources they offer.

2.3 Variables operating at the local level

2.3.1 Socio-economic influences

To evaluate the influence of socio-economic factors on the presence of residential food gardens, variables such as property ownership, income level, and education were included within this study. Property ownership has been one of the most common determinants of residential food gardens in cities such as Portland (OR) (McClintock et al. 2016), Chicago (IL) (Taylor and Lovell 2015), Madison, (EI) (USA) (Smith et al. 2013), and Tasmania, Australia (Head, Muir, and Hampel 2004). Property ownership is often associated with the presence of residential food gardens, as homeowners are motivated to invest in their properties (McClintock et al. 2016). As gardens can take time to establish, individuals renting would have less incentive to construct a garden, as they may not live in same household for more than a year, as leases are renewed annually. Furthermore, high-density housing forms a high percentage of the housing type in the MMC area (Statistics Canada 2016) and therefore, renters may not have access to the back or front yards without the permission of the landlords. For example, in Meaville, (PA, USA) Darby et al. (2020) focussing on rural, low-income household food gardens found renters had a lower motivation to construct and maintain a garden.

Apart from homeownership, income levels were used to discern differences in higher versus lower-income communities. Recent studies have indicated that motivations for gardening can differ depending on income level. For example, in Portland (OR), those with higher income levels were often motivated by environmental or health-related concerns, while low-income individuals were motivated by saving money, having enough food, or for cultural or traditional reasons (Darby et al. 2020; McClintock et al. 2016). Furhtermore, several studies have found greater presence of residential food gardens in higher-income versus low-income communities (Smith and Harrington 2013; Taylor and Lovell 2015; Waliczek, Zajicek, and Lineberger 2005).

Similar results were observed for communities with higher education (McClintock et al. 2016). Greater food scholarship leads to greater knowledge and awareness of food, nutrition and human and environmental health. Thus, educating consumers prompt greater interest to where food comes from and can motivate consumers to grow their own food (McClintock et al. 2016). Therefore, using property ownership, income level, and education as variables to predict the presence of residential food gardens are pertinent for this study and can further be compared to past studies to identify differences and similarities amongst cities.

2.3.2 Ethnicity

As presented in McClintock et al. (2016) and Taylor and Lovell (2015), ethnocultural influences can affect the characteristics of gardens: structure, types of vegetables and fruits grown as well as gardening practices. For many gardeners, gardening is a form of cultural identity as well as a way to mimic the landscapes of their home countries or original town or place (Conway and Brannen 2014; Darby et al. 2020; Head et al. 2004; Hochedez 2018). Furthermore, residential food gardens can be used to grow culturally preferred foods that are not always available in local retail outlets (Diekmann, Gray, and Baker 2018).

Our interest in whether ethnocultural influences have a relationship with the presence of residential food gardens is to discern whether gardens are used to meet dietary and cultural food needs in the MMC area (Taylor and Lovell 2014). For example, in Chicago (IL), concentrations of residential food gardens in neighbourhoods of high Asian ethnicity, and Chinese specifically, often had arbours amongst other forms of gardening infrastructure to grow their food (Taylor and Lovell 2015). Similar findings were found in Malmö, Sweden for immigrants from China and Vietnam (Hochedez 2018). Across three Australian cities, Syndey, Wollongong, and Alice Springs, Macedonian, Vietnamese, and British-born migrant groups were selected and examined to determine the differences across home gardens. Results indicated individuals of different origins grew different types of plants, with varying structures of garden and purposes. For example, gardens managed by Macedonia migrants were focused on vegetable production and often grew tomatoes, chillies, and salad greens (Head et al., 2004, pg. 330). In contrast, gardens tended by Vietnamese migrants were composed of vegetables (sweet potatoes, taro, bok choy) and edible herbs (different varieties of mint and lemongrass) (Head et al. 2004, pg. 332). Therefore, the ethnic background can influence the type of residential food gardens and could help to explain their presence in the MMC area.

2.3.3 Population density

Using population density as an indicator of urban form, to examine the effect of density and presents of residential food gardens was an important variable to include within the analysis. Population density is often intertwined with housing types, as well as the available space in backyards and front yards for residential food gardens. Population density has been used in several mixed-method multi-regression models (Grove, Locke, and O'Neil-Dunne 2014; McClintock et al. 2016) and has been used to hypothesize changes in urban vegetation cover. For example, a recent study found that residential zones in New York City had a negative relationship between population density and urban vegetation, indicating that there was more vegetation in less-dense areas (Grove et al. 2014).

Housing type has shown to have an impact on the presence of home gardens in the state of Ohio (Schupp et al. 2015) as well as spatial patterns of urban green infrastructure in the City of Leizig, Germany (Wang et al. 2019). It accounts for variables that operate at each locale but are omitted from statistic models for the sake of census data. For example, local regulation or policy that allows for or inversely hinders the practice of residential food gardens.

Housing type has been demonstrated to affect urban vegetation (Smith et al. 2005; Wang et al. 2019). For example, in the City of Sheffield, South Yorkshire, UK, the size of backyard gardens was significantly greater in semi-detached and detached housing than terraced housing (two or more adjoining dwellings). Garden size can directly affect the composition of residential food gardens, such as the vegetation grown (Smith et al. 2005). Housing type has also been shown to affect access to urban green infrastructures such as meadows, trees, or other natural areas (Wang et al. 2019).

Furthermore, the spatial distribution of population density, income level, and urban vegetation cover are often interrelated. In Montreal, population density is a strong predictor of urban street cover (Pham et al., 2013). Therefore, although housing types were not included in the study, population density can be used as an indicator of the urban form and the available space for residential food gardens. In sum, there is a need to undertake research on different locations because it can offer further insight on the impact of the built environment on urban green space

2.3.4 Age

Although the family structure was not included in this study, age was incorporated as a variable to mirror lifestyle influences that could affect the presence of residential food gardens. For example, studies have found that females over 50 most often tend to gardens (McClintock et al. 2016). Similar findings were presented in Goddard et al. (2013), where the number of individuals who participated in wildlife gardening was greatest with participants over 65. Age has also been shown to influence the motivations for gardening (McClintock et al., 2016). For example, in Portland (OR), 58% of respondents under 50 reported living more sustainably was an essential reason for gardening (pg. 10), while also achieving greater food self-sufficiency (pg. 10). Participants over 50 shared opposing views and were more concerned with the freshness of food products (McClintock et al., 2016).

Furthermore, for many gardeners, gardening is a form of knowledge transfer from generation to generation. In Darby et al. (2020), respondents often reflected on their gardening experiences as children and what they learned from different family members, friends, and neighbours. From mushroom foraging to harvesting and canning produce, tradition and culture form a significant part of urban gardening. Therefore, using age as a variable to help explain the presence or absence of residential food gardens could shed light on family structure or motivations of having a suburban food garden.

2.4 Synthesis of the conceptual framework

In this chapter, the broad socio-political factors operating at the municipal level were explored based on their influence on the presence of urban agricultural activities, and more specifically residential food gardens. Although the conceptual framework did not reflect their history of urban development, local policy, regulation and programs, these factors do influence the role of the socio-economic factors. Therefore, a mixed regresison model will be used to capture the muncipal-level influences on distribution of residential food gardens.

Concerning local factors, a finer spatial scale will be used to capture their influence at the local level, i.e the dissemination area. Using socio-econmic, ethnocultural, population density and age, these varialbles will be used to explain the spatial distribution of residential food gardens (Figure 2.3). The following chapter will provide a detailed discussion for the spatial and statistical modeling.

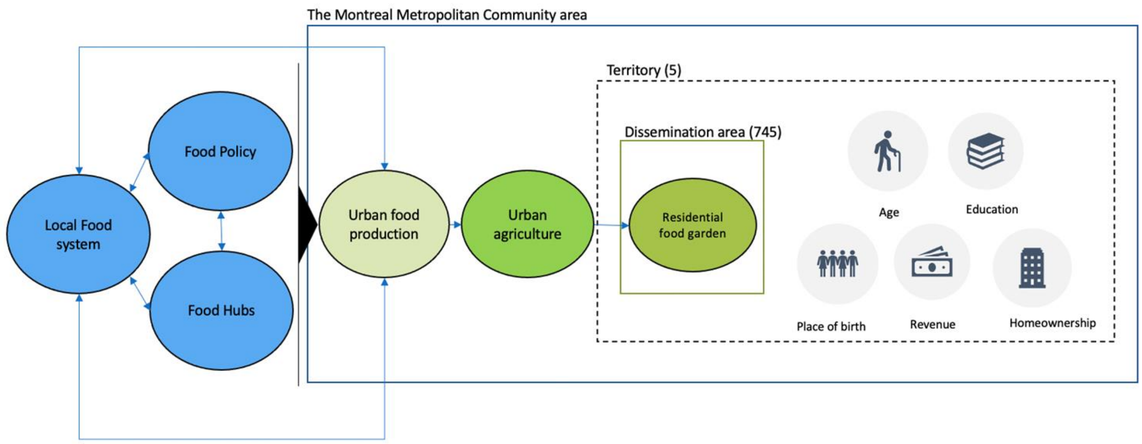


Figure 2.3. Broad socio-political processes operating at the territory level and socio-demographic factors at the dissemination area leve

CHAPITRE III

METHODOLOGIE

3.1 Introduction

The following chapter will describe the methodology used to determine how population profiles influence the presence of residential food gardens across five territories in the MMC area. Divided into four parts, this chapter will first outline the study area and discuss the five territories selected for the analysis. Next, it will present the spatial mapping of residential food gardens within each territory and discuss the socio-economic, urban form and ethnocultural variables used to predict their presence at the macro (dissemination area) and micro (territory) level. Lastly, the methods used for statistic modelling will be presented and discussed.

3.2 Study Area

The MMC area encompasses 82 municipalities, approximately 4 million inhabitants, and covers an area of 4 360 km^2 (MMC 2020). The study's five territories represented roughly 8.4% of the MMC area (366.9 km^2). They were selected due to their diverse socio-economic and ethnocultural profiles as well as differentiating urban form characteristics and total human population. The following map outlines the study area with the selected territories highlighted in yellow (Figure 3.1):

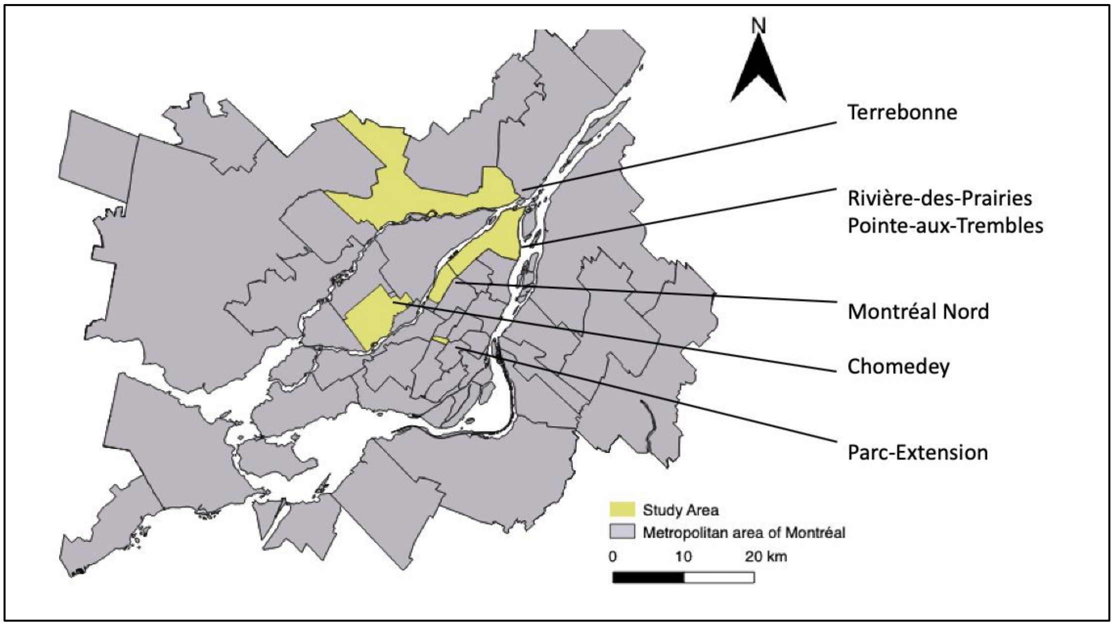


Figure 3.1 Study area: five territories located within Montreal's Metropolitan Community area (Statistics Canada, 2016)

The territories selected were located on and off the island of Montreal, providing diverse conditions for this analysis and availability of garden data.Urban form is most commonly characterised by population density, housing type, layout, landuse and transport infrastructure (Dempsey et al. 2011). Using census data provided by Statistics Canada (2016), housing type and population density were summarised in the following table to classify the urban form of each territory.

Table 3.1 Urban form classification for the five territories

Territory	Area (km2)	Total population	Population density (people/km2)	Housing Type (median, %)			Urban form classification
				Single-detached	Duplex	Apartment less than 5	
Terrebonne	222.4	109,908	494	76%	4%	2%	Suburban
Chomedey (City of Laval)	66.2	124,845	1886	22%	0%	41%	Suburban
RDP-PAT	60.9	106,743	1753	23%	0%	34%	Suburban
Montréal-Nord	15.7	92,438	5888	4%	11%	61%	Urban
Parc-Extension	1.7	28,278	16634	0%	6%	83%	Urban

Montreal-Nord and Parc-Extension were the smallest territories characterized by high population densities in comparison to the three other territories in this study. Furthermore, their housing type was dominated by duplex’s and apartment buildings less than five stories, and thus were classified as urban territories. Terrebonne was classified as a suburban territory due to the significant presence of single-detached housing and low-population density. Although single-detached housing was present in Chomedey and Rivière-des-Prairies-Pointe-aux-Trembles (RDP-PAT), the most predominant housing type was apartment buildings less than five stories. With similar population densities, Chomedey and RDP-PAT were classified as suburban territories, as they both had low population densities in comparison to Montreal-Nord and Parc-Extension (many thanks to Costanza Graziani (student) and Anna-Liisa Aunio (supervisor, professor and researcher) at Dawson College who provided the location of residential food gardens in Parc-Extension).

3.2.1 Socio-economic data across the territories

Socio-economic data was downloaded from Statistics Canada (2016) by dissemination area to better understand each territory's societal context. The following table provides a summary of the population profiles for each territory followed by two thematic maps illustrating the population density and percentage of citizens earning below \$20,000 after-tax per year. Both the table and maps provided greater insight on the differences and similarities between and within each territory.

Table 3.2 Median values of density and socio-demographic and economic profile by territory

Theories	Variables	Variable description	**MMC	Terrebonne	Chomedey	Montreal Nord	RDP_PAT	Park-Extension
	Dependent variable COUNT_JAR Level 1 - dissemination area (n=745) Level 2 - Territority (n=5) **Independent variables**	Number of dissemination areas per territory	6261	181.0	173.0	155.0	185.0	51.0
Urban form	Total population		4 098 927	109908.00	124845	92438	106743	28278
	POP_DEN	Population density (persons/km2)	890	494	1886	5888	1753	16634
Social Strat.	*PCT_CAN	% of Canadian citizens	92%	97.0%	90%	85.6%	94.7%	77.9%
	*PCTAGE_20_34	% of citizens between the age of 20-34	20%	17.2%	18.1%	19.0%	17.8%	24.0%
	*PCTAGE_50_64	% of citizens between the age of 50-64	20.5%	22.8%	20.1%	19.0%	23.8%	16.6%
	*PCTAGE_65_OV	% of citizens 65 years of age and over	16.4%	11.4%	17.9%	15.1%	15.8%	15.8%
	*PCTEDU_UN_AB	% of citizens with a univeristy degree or above	9.6%	8.2%	13.7%	11.0%	9.9%	15.4%
Economic demographics	*PCTTOT_OWN	% of citizens who are home owners	56.0%	84.8%	56.8%	28.0%	69.8%	19.9%
	*Median individual income		$ 33,040.00	$ 32,256.00	$39,954.00	$ 22,720.00	$ 28,224.00	$ 18,592.00
	*PCTINAF_Less20	% of citizens who earn less than $20 000, a/f tax	11.5%	26.9%	37.5%	40.5%	31.2%	52.3%
	*PCTINAF_80_More	% of citizens who earn more than $80 000, a/f tax	11.8%	2.8%	1.9%	0.6%	2.3%	0.0%

** Using Statistics Canada's Census data (2016), the percentage for each variable was calculated for each dissemination area. The value represented in the table is the median value.*
*** Data from the MMC was taken from the population profiles summary (2016) produced by the City of Montréal and Statistics Canada (2016)*

**Using Statistic's Canada Census data (2016), as well as data provided by the City of Terrebonne and the City of Laval, the percentage for each variable was calculated for each dissemination area. The value represented in the table is the median value*

***Data for the MMC was taken from the population profiles summary (2016) produced by the City of Montreal and Statistic's Canada (2016)*

First, population density was the greatest in the territories located on the island of Montreal. For example, Parc-Extension had the most significant number of dissemination areas with just under 20,000 inhabitants per kilometre squared followed by Montreal-Nord (5888 people/km^2) and RDP-PAT (1753 people/km^2). For Terrebonne (494 people/km^2) and Chomedey (1886 people/km^2), located off the island of Montreal, Chomedey had a greater population density.

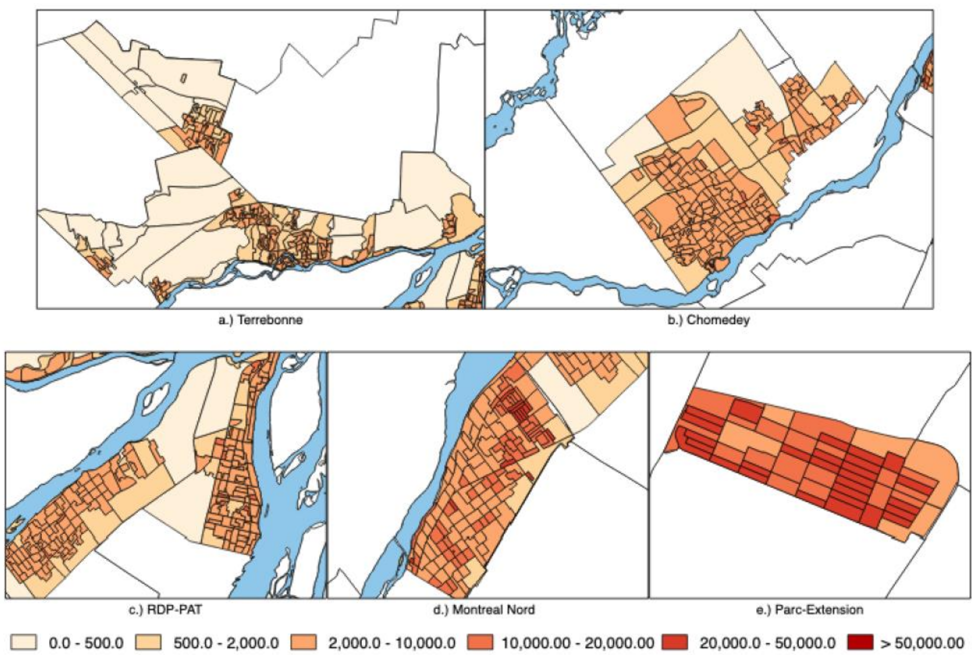


Figure 3.2 Population density across five territories (people/km^2)

Each territory had contrasting social stratification with Parc-Extension with the lowest percentage of Canadian citizens (median value of 77.9%), the younger population (median value of 24%) and the greatest percentage of citizens with a univesity degree or greater (median value of 15.4%). Following a similar social stratification was Montreal-Nord with a slightly greater number of Canadian citizens (median value of

85.6%) and greater percentage of citizens between the ages of 50 and 64 (median value of 19%) and lower percentage of individuals with a university degree or greater (median value of 11 %). RDP-PAT and Chomedey had a greater proportion of Canadian citizens (median value of 94.7% and 90%) with similar proportions of citizens between the ages of 20 and 34 (17.8% and 18.1%) and ages of 50 and 64 (23.8% and 20.1%). Chomedey had the greatest proportion of citizens over 65 (median value of 17.9%), while RDP-PAT had a value of 15.8% (similar to Montreal-Nord and Parc-Extension). Lastly, Terrebonne had the greatest proportion of Canadian citizens across the dissemination areas (median value of 97%), had the lowest proportion of citizens over 65 (11.4%) as well as the lowest proportion of citizens with an university degree or above (8.2%).

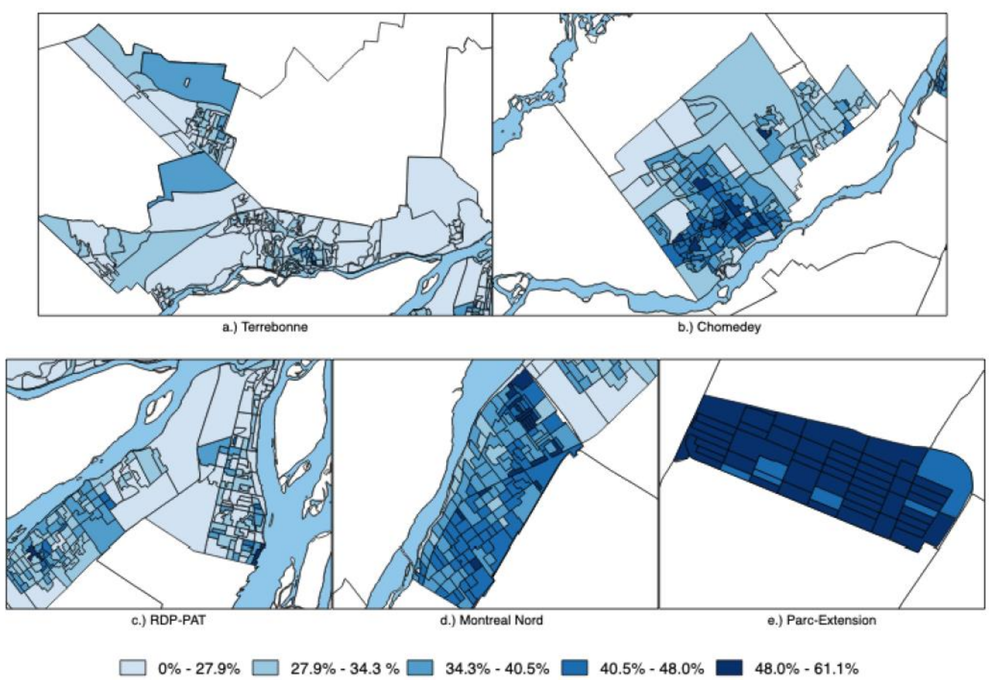


Figure 3.3 Percentage of the population earning less than \$20,000 per year after-taxes across the five territories

Low-income communities were concentrated on the island of Montreal with Parc-Extension with the greatest percentage of citizens earning \$20,000 or less (median value of 52.3%), followed by Montreal-Nord (medium value of 40.5%). Citizens in Chomedey earning \$20,000 or less (medium value of 37.5%) were clustered in the south-west portion of the territory in the residential zone. RDP-PAT had a slighltly lower percentage of people earning this brakcket of income (31%). Lastly, Terrebonne represented the fewest residents earning an income of \$20,000 or less (2.8%).

In contrast to the percentage of citizens earning an income of \$20,000 and below, Terrebonne had the greatest proportion of citizens earning \$80,000 and above (median value of 2.8%), followed by RDP-PAT (2.3%), Chomedey (1.9%), Montreal-Nord (0.6%) and Parc-Extension (0%).

3.3 Data

3.3.1 Mapping residential food gardens

Data identifying the number and size of residential food gardens were aggregated from five previous studies completed by master's students from AU/LAB between 2017 – 2019. Spatial data for the territory of Terrebonne was completed by Cécile Reynaud (2018), Chomedey (City of Laval) was provided by Myriam Belzile (2018), Montreal-Nord was provided by Bastien Haehnel (2017), and RDP-PAT was provided by Maylis Blanc (2018). These studies followed the methodology presented in Taylor & Lovell (2012) and McClintock et al. (2016) to identify residential food gardens using satellite imagery. Furthermore, each of the studies provided a spatial analysis of the distribution of residential food gardens. Discussions predominantly pertained to the garden size and location.

For Parc-Extension, the identification of residential food gardens was completed in two steps. First, using data collected by Costanza Graziani, surpervised by Anna-Liisa Aunio from the department of sociology at Dawson College, provided the location of residential food gardens in Parc-Extension. The data was collected directly in the field between 2016 – 2017. To ensure all residential food gardens were identified in Parc-Extension, the methodology presented in Taylor & Lovell (2012) and McClintock et al. (2016) was also used to identify any remaining gardens using satellite imagery.

3.3.2 Data mapping validation via ground-truthing

Field validation provided an opportunity to discern the quality of the garden identification process using satellite imagery (Parc-Extension was exempt from this process). Ground-truthing was completed using a 2% random sample from the number of residential food gardens in each territory to validate the accuracy of the garden identification process. Points mistakingly identified as gardens, otherwise known as false positives, ranged from 1.0% to 2.0% across each of the four territories (excluding Parc-Extension). As residential food gardens can vary in size, some were not visible using satellite imagery. In this case, gardens that were not mapped, were known as false negatives or undercounting. As the identification of residential food gardens occurred between 2017 and 2020, an undercount in the number of residential food gardens could be caused by a few factors. First, property sale or change in tenants can affect the use of back or front yards, and thus, the presence of residential food gardens. For Parc-Extension, field validation was not completed as only 18% of the gardens were identified using satellite imagery (168 gardens out of 888).

Table 3.3 Percentage of false negatives across each territory

Territory	% Undercount
Terrebonne	22%
Chomedey	2%
Montreal-Nord	17%
RDP-PAT	12%
Parc-Extension	-
Total number of residential food gardens identified	8172

Results for false positives and negatives (overcount versus undercount) were similar to those reported in Portland (OR) by McClintock et al. (2016). However, in a similar study in Chicago (IL) by Taylor & Lovell (2012), no undercounts were reported, and the false positives were, on average, 14.5%. Therefore, identifying residential food gardens using satellite imagery is accurate; however, discrepancies are possible depending on the year the satellite imagery was taken as well as its quality. To ensure robustness and quality of the garden identification process, Eric Duchemin, co-director of this study, performed a final verification of all garden cartography identified through satelite imagery.

3.3.3 Data preparation for spatial maping and statistical analysis

The following describes the steps completed to analyze the spatial distribution of residential food gardens.

1. Residential food gardens were identified using methods presented in McClintock et al. (2016).
2. First, the location of residential food gardens across the five territories was uploaded from MyMaps as a KML file and loaded onto QGIS as a point layer.

MyMaps is a branch from Google Satellite imagery, enabling users to identify attributes using points or polygons. Each point layer was then saved as a shapefile and included attributes such as an ID specific to each garden, the size, and whether it was located in the back or front yard. Although some territories also included collective and community gardens, only residential food gardens were retained for this study. Data for all the residential food gardens were then merged into one shapefile.

3. For each territory, descriptive statistics (maximum, minimum, mean, median, and the standard deviation) were calculated for the number of residential food gardens and their corresponding size.
4. Following the analysis at the territory level, the dissemination area, the smallest geographical unit available from Statistics Canada (2016), was used to examine the number and size of residential food gardens within each dissemination area. The dissemination area was chosen to depict the variance of residential food gardens as it is delineated by population blocks of 400-700 persons (Statistics Canada 2018) providing more homogenous socio-economic demographics (Pham et al. 2013, 2017). A total of 745 dissemination areas were located within the five territories in the study area.
5. Using R-Studio (version 1.2.5), the distribution of residential food gardens was illustrated using five histograms. Examining the distribution of residential food gardens across each territory was an essential step. It impacted the type of statistic modelling used to analyze the association between residential food gardens and the socio-economic variables. A total of 134 dissemination areas did not contain residential food gardens, representing 18% of the dissemination areas within the study area (134/745). Territories such as RDP-PAT had the greatest number of dissemination areas with no residential food gardens, followed by Chomedey, Montreal Nord, Terrebonne, and Parc-Extension. A negative binomial regression model was used to analyze the data statistically to accommodate the data's negative binomial distribution.

3.4 The variables analyzed

3.4.1 Socio-economic variables

Data including age, homeownership, income, and education were downloaded by the MMC area's dissemination area. Once the data was downloaded into excel, the data was then clipped to the study area by matching each dissemination area's ID from the downloaded dataset to each territory's dissemination area in QGIS. Percentages for each variable were then calculated by dividing the variable by the total population, the total number of dwellings (for the percentage of homeowners), or the total number of citizens earning an income (for income categories). The following table outlines the descriptive statistics for each of the socio-economic variables. It should be noted that there where some dissemination areas without households, explaning the minimum value of zero in the tables outlining the description of the socio-economic variables.

Tableau 3.2 Description of socio-economic variables

Theories	Variable description	Min.	Max.	Median	Mean	Std.dev
Social Strat.	% of citizens between the age of 20-34	0.00	39.64	18.14	18.44	4.80
	% of citizens between the age of 50-64	0.00	43.91	20.87	21.35	5.39
	% of citizens 65 years of age and over	0.00	86.87	15.21	17.20	10.97
	% of citizens with a univeristy degree or above	0.00	44.86	10.95	11.75	6.20
Economic demographics	% of citizens who are home owners	0.00	100.00	56.54	55.63	30.88
	% of citizens who earn less than $20 000, a/f tax	0.00	61.11	33.93	34.66	10.09
	% of citizens who earn b/w $20-$39 000, a/f tax	0.00	65.69	35.85	34.92	6.99
	% of citizens who earn more than $80 000, a/f tax	0.00	26.09	1.56	2.27	2.71

3.4.2 Urban form characteristics

Using the same method for the socio-economic data, variables including population density and housing type were download from Statistics Canada (2016) by dissemination area, clipped and matched to each territory's corresponding area. Housing type was not used in the statistic analysis. However, it was used to provide a visual assessment of the housing types within each territory. To simplify the statistical analysis, the population density was used as an indicator of urban form: higher population densities indicate higher density housing such as multistorey buildings or row-housing. The following table summarizes the descriptive statistics for population density and housing type:

Tableau 3.3 Descriptive statistics of population density and housing type

Theories	Variable description	Min.	Max.	Median	Mean	Std.dev
Urban Form	Population density	0.00	159767.40	5013.90	7042.08	8370.25
Housing Type	% of occupied single-detached housing	0.00	100.00	20.24	33.44	33.64
	% of occupied semi-detached housing	0.00	90.91	2.56	8.70	14.75
	% of occupied buildings greater than 5 storeys	0.00	100.00	0.00	3.65	14.26
	% of occupied row housing	0.00	88.46	0.00	3.68	11.40
	% of occupied duplex's	0.00	68.75	2.86	7.40	11.35
	% of occupied building less than five storeys	0.00	100.00	42.11	42.10	33.82

3.4.3 Ethnocultural demographics

Examining whether ethnocultural diversity influenced the distribution of residential food gardens was the premise of this study. As immigrant populations formed up to 22 % of each territory (with Parc-Extension with the most significant percentage of immigrants), selecting the most frequent immigrant populations was completed using the City of Montreal's population profile summaries (2016). For the City of Terrebonne and Chomedey, we consulted the municipal bureau to provide this information. Using "Place of birth" as the indicator of ethnic diversity-focused, our study on first-generation inhabitants born outside of Canada. Although the second and third generations could influence residential food gardens distribution, we chose to focus on first-generation immigrants' effects. Although other studies have used linguistic identities to determine ethnocultural diversity (Pham et al. 2017), we decided to use the place of birth based on a consultation with an immigration specialist.

Therefore, using "Place of birth" as an indicator of ethnic diversity, seventeen places of birth were selected and then truncated into ten groups representing the sub-continent of their geographical location (Table 3.5). The ethnic population had a cumulative average of 2% or greater of the total population across each territory for each ethnic group. Ensuring a cumulative average of 2% or greater ensured each place of birth was present within each territory, as their absence could affect the statistic modelling results (Table 3.5).

Table 3.4 Place of birth selected and associated sub-continent groups

Group	Place of birth
South Asia	India, Sri Lanka
East Asia	China, Vietnam
Middle East	Lebanon
North Africa	Algeria, Morocco
Western Europe	France
Mediterranean	Italy, Greece
South-Western Europe	Portugal
Central Europe	Romania
Latin America	Columbia, Peru, EI Salvador, Mexico
Caribbean	Haiti

3.4.4 Spatial patterns of socio-economic variables by territory

To better understand the variance of the place of birth across each territory, Table 4.5 highlights the territories with the greatest ethnic diversity, with immigrants population groups formings 2% or greater of the total immigrant population in each territory highlighted in yellow. Chomedey, Parc-Extension, and Montreal-Nord represented the greatest ethnic diversity amongst the five territories. Territories with the least diversity included Terrebonne, followed by RDP-PAT.

Tableau 3.5 Immigrant population percentage of the place of birth for each territory

Group	Terrebonne	Chomedey	Montreal-Nord	RDP-PAT	Parc-Extension
South Asia (India, Sri Lanka)	0.02	2.72	0.16	0.07	2.87
East Asia (China, Vietnam)	0.34	3.11	1.10	0.56	3.58
Middle East (Lebanaon)	0.15	9.95	1.25	0.23	0.32
North Africa (Algeria, Morocco)	1.29	11.54	6.98	2.04	5.76
Western Europe (France)	0.57	2.66	0.50	0.48	1.84
Mediterranean (Italy, Greece)	0.47	9.32	3.82	5.82	4.65
South Western Europe (Portugal)	0.18	2.52	0.36	0.41	1.35
Central Europe (Romania)	0.21	4.21	0.21	0.40	0.23
Latin Ameria (Mexico, Columbia, Peru, El Salvador)	0.67	4.75	2.42	1.37	3.08
Caribbean (Haïti)	2.79	9.62	12.29	7.28	5.21

Source: Ville de Montreal, 2016, as well as consulted the territory of Terrebonne and Chomedey to complete calculations. Furthermore, it was created with the City of Montreal's population profile summaries. For Parc-Extension, the group counts are under representative as the population profile encompasses Villeray and St. Michel.

Immigrant populations, including North Africa, the Mediterranean, and the Caribbean, formed over 60% of each territory's immigrant population. The following boxplots illustrate the distribution of the three most abundant ethnic groups across the five territories. Citizens born in the Mediterranean_Europe region (Italian and Greek origins) were the most abundant in RDP-PAT, Chomedey and Montreal-Nord (Figure 3.4). Immigrants from the Caribbean (Haitian origins) were most abundant in RDP-PAT and Montreal-Nord (Figure 3.5). Lastly, North-African immigrants (Algerian and Moroccan origins) were most concentrated in Montreal-Nord, followed by RDP-PAT (Figure 3.6).

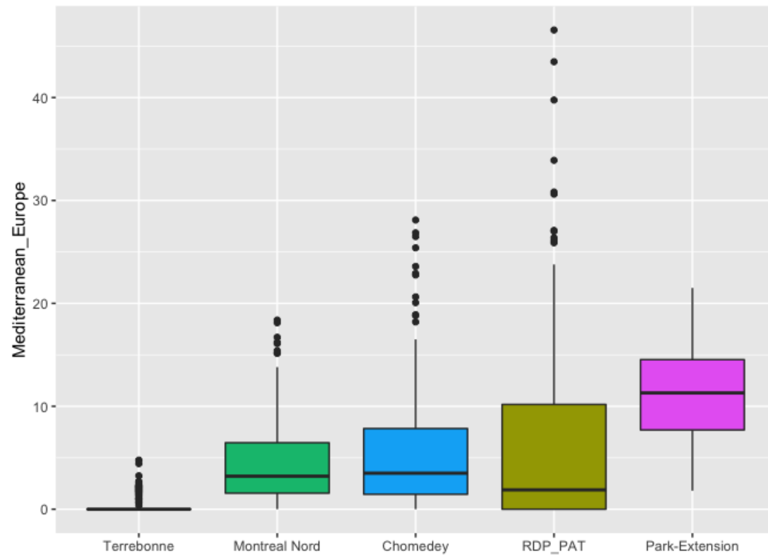


Figure 3.5 Box-plot illustrating the distribution of immigrant populations from the Mediterranean across each territory

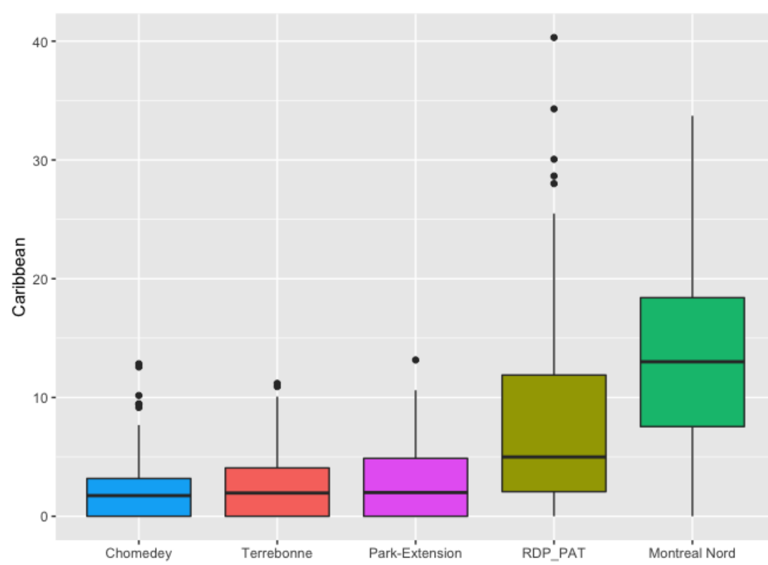


Figure 3.6 Box-plot illustrating the distribution of immigrant populations from the Caribbean across each territory

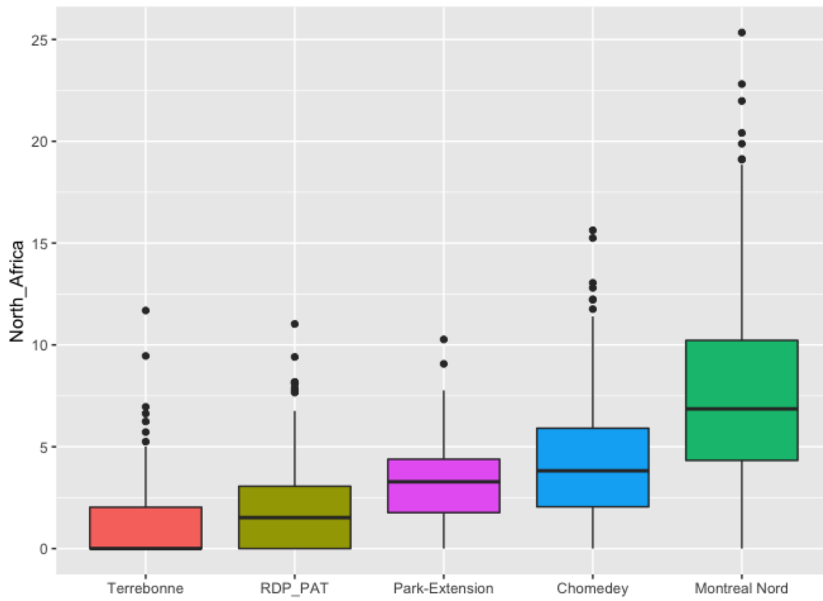


Figure 3.7 Box-plot illustrating the distribution of immigrant populations from North Africa across each territory

Therefore, ethnocultural diversity, although present, is not evenly distributed across each territory. Taking the ethnocultural-spatial patterns into consideration during the statistical analysis will be imperative. A greater concentration of different ethnocultural groups can influence local landscapes and participation in urban agricultural activities. As mentioned the previous chapter, different cultural groups' identities can affect local policies and social norms.

Tableau 3.6 Descriptive statistics for ethnocultural groups

Theories	Variable description	Min.	Max.	Median	Mean	Std.dev
Ethnocultural groups	% of citizens from South Asia	0.00	24.46	0.00	1.15	3.32
	% of citizens from East Asia	0.00	9.86	0.00	0.78	1.38
	% of citizens from the Middle East	0.00	22.40	0.00	1.74	3.39
	% of citizens from North Africa	0.00	25.34	2.52	3.61	4.08
	% of citizens from Western Europe	0.00	6.65	0.00	0.56	0.98
	% of citizens from Southwestern Europe	0.00	15.51	0.00	0.50	1.17
	% of citizens from Central Europe	0.00	12.22	0.00	0.49	1.21
	% of citizens from Latin America	0.00	16.79	0.00	1.53	2.18
	% of citizens from the Caribbean	0.00	40.31	3.32	5.91	6.95

3.5 Data analytical methods

3.5.1 Spatial data analysis

Using QGIS, spatial mapping was completed to illustrate their distribution of residential food gardens by count and size (median) for each territory. The following outlines the process used to create both maps:

1. To summarize the number of residential food gardens in each dissemination area, the analysis tool "Count points in polygon" in QGIS was used. Next, the garden area was summed within each dissemination area. Using the data management tool, "Join attributes by location," the dissemination area (target vector layer) was joined with the residential food gardens layer (join vector layer). By selecting the "take summary of interesting features," each residential food garden's total area was summed for each the dissemination area.
2. As the size of the residential food gardens ranged from 1.6 meters to over 1000 meters, the gardens' size was summed by the dissemination area and illustrated using a thematic map. Mapping the size of residential food gardens gives greater insight into the growing capacity of the gardens.

3. Lastly, spatial autocorrelation of residential gardens, that is, the probability of neighbourhood spatial influence on the presence of residential food gardens, was completed using GeoDA. Local Moran's I, a local spatial autocorrelation (LISA) statistics, was used to calculate the local spatial autocorrelation for the number of residential food gardens across each dissemination area (Anselin 2020; Pham 2013). A Queen weighted matrix's with 999 permutations was used to determine the level of significance,displaying the level of confidence , which was divided into four levels: high-high, high-low, low-low and low-high (Anselin 2020).

3.5.2 Statistical modelling analysis

The count of residential food gardens (dependent variable) and the socio-economic variables (independent variables) was uploaded into R Studio (version 1.2.5). This study's data were nested into two levels: level one representing the relationships across the dissemination area, and level two at the territory level. The following presents the tests and data processing and analysis completed to ensure data quality and model robustness.

3.5.2.1 Multicollinearity

Testing whether variables exhibited multicollinearity was a preliminary step to ensure variables were not internally influenced, hence avoiding overfitted models. One of the most common indices used to test multicollinearity was the variation inflation factor (VIF). Of the 45 variables tested, 20 variables were retained and had a VIF score of less than 5. The cut-off value for the VIF can vary throughout the literature. For example, d'Astous (1952) recommended retaining VIF scores of 2.5 or less as they may exhibit severe multicollinearity (pg. 325). However, in Bressoux (2008), VIF scores of less than 5 were accepted. In comparison, Grove et al. (2014) retained VIF scores of 7.5 or below and concluded that VIF scores of 10 or greater required further evaluation and were not retained for statistical investigation (O'brien, 2007 cited in Grove 2014, pg. 409). Thus, variables with a VIF of 5 or less were retained for the statistic modelling analysis to ensure low levels of multicollinearity (Table 3.8):

Table 3.8 Variance inflation factor scores for independent variables

Independent variables	**GVIF**
Urban form	
POP_DEN	1.589
Social Strat.	
PCTINAF_Less20	3.188
PCTINAF_80_More	1.953
PCTEDU_UN_AB	2.095
PCTTOT_OWN	3.158
PCT_CAN	1.803
PCTAGE_20_34	2.304
PCTAGE_35_49	2.617
PCTAGE_50_64	2.028
PCTAGE_65_OV	3.376
Ethnocultural	
South_Asia	3.467
East_Asia	1.191
Middle_East	2.01
North_Africa	1.758
Western_Europe	1.071
Mediterranean_Europe	1.513
South_Western_Europe	1.142
Central_Europe	1.185
Latin_America	1.187
Caribbean	2.043

3.5.2.2 Testing data normality

Before testing the data's normality, all independent variables were scaled to converge models and avoid singular fit errors. Using the Shapiro-Wilk and Kolmorov-Smirnov (K-S) test, all variables were tested for normal distribution and had a p-value of less than 0.05. All variables had a p-value of less than 0.05, indicating abnormal distributions. Furthermore, the distribution of the dependent variable followed a negative binomial distribution, showcasing a high number of dissemination areas that did not contain residential food gardens (Figure 3.7). This was taken into consideration when conducting the regressions (see the next section on modelling).

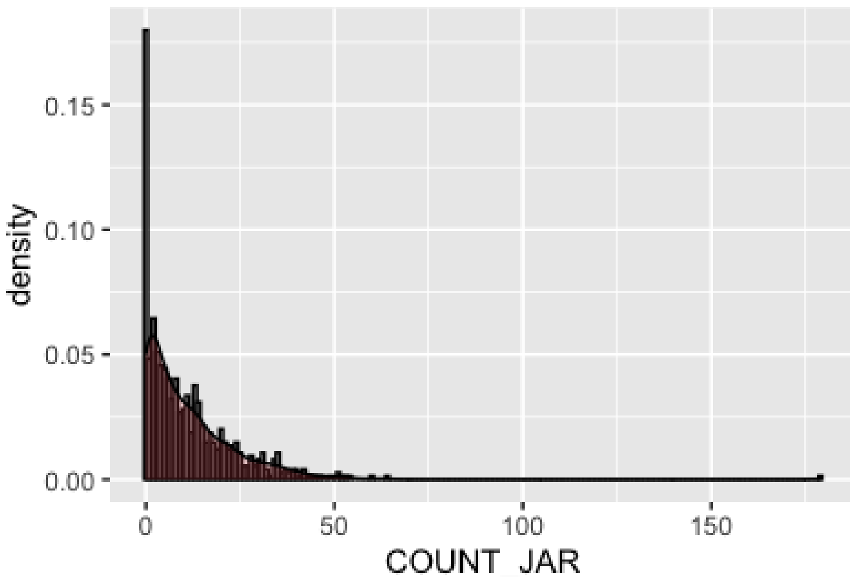


Figure 3.7. Distribution of residential food garden data

3.5.2.3 Multivariate regression models

Three multivariate regression models were used to analyze the dependent and independent variables, examine their relationships, and determine the probability of residential food gardens across and within the five territories examined in this study. The models used within this study include: fixed-effects Poisson regression model, fixed-effects negative binomial regression model, as well as a mixed-effects (random and fixed) negative binomial regression models.

The fixed-effects Poisson regression model

Because our dependent variable counted the number of residential food gardens in each dissemination area, the data did not meet the normal distribution requirements for a linear regression model. Thus, with a high number of zeros within the dataset, a Poisson regression analysis using the glm function provided in the stats package (R Core Team and contributors worldwide) of R Studio (version 1.2.5) was used to analyze the effects of the socio-economic variables on the number of residential food gardens in each dissemination area. Furthermore, for a least-squared model, the response variables can vary from negative to positive (Grace-Martin 2020). An overdispersion function was utilized to ensure the mean was proportional to the variance. Overdispersion functions are commonly used to ensure the quality of the model.

As Poisson distributions are used to predict the probability of an event, the following equation describes the model used in this analysis:

$$P(k \text{ events in interval}) = \frac{\lambda^k e^{-\lambda}}{k!}$$

- k represents the number of times an event occurs; this variable is an integer and can have a value of 0, 1, 2…
- λ represents the average number of events per interval

Function (command) used in RStudio for the empty model:

m0 <- glm(COUNT_JAR ~ 1,data=RG_Data4, family=poisson)

Command for model 1:

```
m1 <- glm(COUNT_JAR ~ POP_DEN_1000 + PCTINAF_Less20 +
        PCTINAF_80_More + PCTEDU_UN_AB + PCTTOT_OWN_10 +
        PCT_CAN_10 + PCTAGE_20_34 + PCTAGE_35_49 + PCTAGE_50_64 +
        PCTAGE_65_O  + South_Asia + East_Asia + Middle_East + North_Africa +
        Western_Europe + Mediterranean_Europe + South_Western_Europe +
        Central_Europe + Latin_America  + Caribbean,
        data = RG_Data4, family=poisson)
```

The fixed-effects negative binomial regression model

Due to the data's overdispersion in the fixed Poisson model, a fixed negative binomial model (*glm.nb* function provided in the MASS package in R-Studio 1.2.5) was then used to illustrate the associations between residential food gardens and socio-economic variables. Negative binomial models are commonly used for overdispersed count-data and accommodate the overdispersion by adding an extra parameter within the model (Group, UCLA: Statistical Consulting n.d.). A null model was first used to breakdown the variance amongst the 20 variables retained from the VIF test. Next, variables were added one-by-one to ensure the model's robustness.

Command used in RStudio for model 2, all variables:

```
m2 <- glm.nb(COUNT_JAR ~ POP_DEN_1000 + PCTINAF_Less20 +
        PCTINAF_80_More + PCTEDU_UN_AB + PCTTOT_OWN_10 +
        PCT_CAN_10 + PCTAGE_20_34 + PCTAGE_35_49 + PCTAGE_50_64 +
        PCTAGE_65_OV + South_Asia + East_Asia + Middle_East + North_Africa +
        Western_Europe + Mediterranean_Europe + South_Western_Europe +
        Central_Europe + Latin_America + Caribbean,
        data = RG_Data4)
```

Mixed-effects (random and fixed) negative binomial regression models

The mixed negative binomial model (*glmer* function provided in the lme4 package in R-Studio 1.2.5) was set to vary at the territory level to examine whether the association between residential food gardens and the significant variables (identified in the fixed negative binomial model) varied across the five territories.

Because the residential food gardens data was “count data,” we used a generalized linear mixed-effects model and specified the distribution as a negative binomial. As the variables were added to the model one at a time, variables that increased the AIC value were omitted from the analysis. Of the 20 independent variables retained through the VIF test for multicollinearity, only 14 variables remained, as their addition lowered or did not affect the AIC value. Model 3 was separated into 4 models, a null model (called as model 3a) to test the variance of the dependent variable, a second model (model 3b) with only the social stratification variables, a third model (model 3c) with only the ethnocultural variable and a final model (model 3d) with all the variables.

Command used in RStudio for model 3d, all variables with randomly varying intercepts:

```
mer3d <- glmer.nb(COUNT_JAR  ~ POP_DEN_1000 +PCTINAF_Less20_10 +
        PCTINAF_More80_10 + PCTEDU_UN_AB_10 + PCTTOT_OWN_10 +
        PCTAGE_20_34_10 + PCTAGE_50_64_10 + South_Asia_10 +
        Middle_East_10 + North_Africa_10 + Mediterranean_Europe_10 +
        Latin_America_10 + (1 | TERRITOIRE),
        data = RG_Data4,
        control=glmerControl(optimizer="bobyqa",optCtrl=list(maxfun=2e5)))
```

Finally, I conducted a mixed model (model 4) following model 3d, in which the significant variables were tested with random effects to discern whether their relationship across each territory resembled. For example, the following model command was run in RStudio to discern the relationship between residential food gardens and population density across each of the five territories:

Command used in RStudio for model 4, all variables with randomly varying independent variables and intercepts:

```
mer4 <- glmer.nb(COUNT_JAR ~ POP_DEN_1000 +PCTINAF_Less20_10
    +PCTINAF_More80_10 + PCTEDU_UN_AB_10 + PCTTOT_OWN_10 +
    PCTAGE_20_34_10 + PCTAGE_50_64_10 + South_Asia_10 +
    Middle_East_10 + North_Africa_10 + Mediterranean_Europe_10 +
    Latin_America_10+(1|TERRITOIRE) + (0+ POP_DEN_1000|TERRITOIRE),
    data=RG_Data4,
    control=glmerControl(optimizer="bobyqa",optCtrl=list(maxfun=2e5)))
```

3.5.2.4 Validating model robustness

The Akaike information criterion (AIC) was used to test each model's robustness and assess its goodness of fit (University of Alberta n.d.). The AIC calculates "the number of parameters minus the likelihood of the overall model" (University of Alberta, s.d.); the lower the AIC, the more robust the model. Following the AIC test, an intra-class coefficient (ICC) using the sjmisc package in R-studio was calculated for models containing mixed, fixed and random effects. The ICC indicates the proportion of the variance unaccounted for in DA or the territory level (Pham et al. 2017, pg. 428), by calculating "the proportion of between-tract variance in the total variance" (Pham et al., 2017, 428); where σ_u^2 and σ_e^2, represents the between-tract covariance. The following provides and describes the ICC equation:

$$ICC = \sigma_u^2 / \left(\sigma_u^2 + \sigma_e^2\right)$$

- If the ICC is close to 1, it indicated a high similarity amongst the group's variables.
- If the ICC is closer to 0, it indicated a low similarity amongst the group's variables.

In addition to the ICC, the marginal and conditional r-squared was computed. The marginal r-squared represents the variance explained by the fixed effects. In contrast, the conditional r-squared "is interpreted as a variance explained by the entire model, including both fixed and random effects" (referred to R-Studio version 1.2.5, help section). Marginal and conditional r-squared values were calculated using the MuMin (version 1.43.17) and *r2glmm* package for generalized mixed-effects models. The r squared marginal value represents the variance of the fixed effects, while the r squared conditional value indicated the variance for the entire model, both random and fixed effects (R-Studio version 1.2.5, help section).

Furthermore, to compute the model's maximum likelihood, McFadden's pseudo-r-squared was added (UCLA: Statistical Consulting Group n.d.). McFadden's pseudo-r-squared provides the log-likelihood of improvement between the intercept model and the full model with a value of less than or equal to zero. Thus, McFadden's pseudo-r-squared value would be higher for the model with the greatest likelihood.

Finally, the Incidence Rate Ratio (IRR) was used to calculate the likelihood of residential food gardens' presence under different societal contexts. Exposures to other variables can have differing effects, and thus, this variable attempts to better discern which variables have the most significant influence.

3.6 Summary

This chapter presented the methodology utilized to identify, map, and statistically model the socio-spatial relations of residential food gardens across and within each of the five territories. It also provided an in-depth description of the variables (chosen based on the scientific literature) used within the study and their significance in determining their influence on the spatial patterns of residential food gardens in the MMC area as well as how population profiles are associated with the presence of residential food gardens. The following chapter will present the results of the spatial and statisical modeling.

CHAPTER IV

RESULTS

4.1 Introduction

The chapter presents the results derived from the spatial mapping and statistical modelling of residential food gardens. In the statistical modelling, since my multivariate regression models were tested at two hierarchy levels: the dissemination area and territory level using both fixed and random effects, the chapter presents the results following the two hierarchy levels: global affect by dissemination area and local effect by territory.

4.2 Spatial mapping of residential food gardens across the dissemination areas

In the five territories, 8172 residential food gardens were identified throughout 745 dissemination areas. Although their density varied across each territory, our results validate that residential food gardens are present in the MMC area and outnumber other forms of urban agriculture. The following illustrates the concentration of residential food gardens across the dissemination areas of each territory.

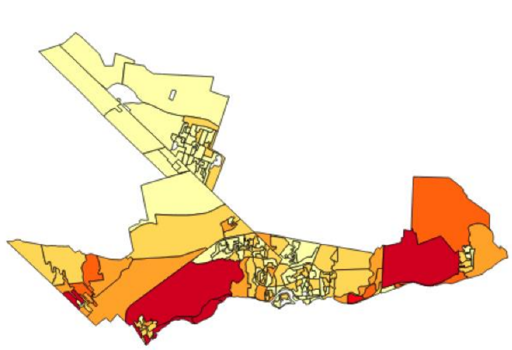
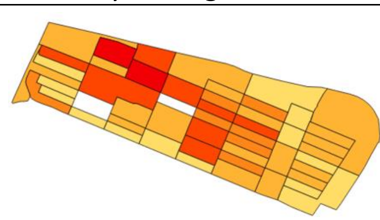
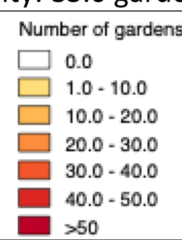
	
Terrebonne Area: 222.4 km^2 Number of gardens: 2309.0 Density: 10 .0 gardens/km^2	**Chomedey** Area: 66.2 km^2 Number of gardens: 2330.0 Density: 35.0 gardens/km^2
	
Rivière-des-Prairies Pointes-aux-Trembles Area: 60.9 km^2 Number of gardens: 1329.0 Density: 22.0 gardens/km^2	**Montreal-Nord** Area: 15.7 km^2 Number of gardens: 1310.0 Density: 83.0 gardens/km^2
	
Parc-Extension Area: 1.7 km^2 Number of gardens: 888 Density: 522 gardens/km^2	

Figure 4.1 Concentration of residential food gardens across each territory

Terrebonne and Chomedey (Laval) had distinct clusters of residential food gardens (dissimination areas with greater than 50 residential food gardens). In both territories, residential food gardens were concentrated in urban residential zones (verified using Google Earth). In Terrebonne, these areas were located along the southern border of the territory. In Chomedey, the concentration was located in the central eastern part of the territory. In RDP-PAT, a small concentration of gardens (ranging between 10 to 30 residential food gardens per dissimination area) were located in the south-eastern area of the territory. The remaining dissmination areas of RDP-PAT had a low concentration of residential food gardens (1 to 10 residential food gardens per dissimination area). Montreal-Nord and Parc-Extension were more homogenous in their distribution of residential food gardens. Although Parc-Extension did have a few areas with up to 50 gardens, the average ranged between 10 to 30 residential food gardens throughout the territory.

4.2.1 Prevalence of residential food gardens by territory

Chomedey had the most significant number of residential food gardens (roughly 29%), followed by Terrebonne (28%). The density of residential food gardens ranged from 10 gardens per kilometre squared in Terrebonne to 522 gardens per kilometre squared in Parc-Extension. However, it is important to recognize the difference in territory size and population density: Parc-Extensions is over one-hundred times smaller than Terrebonne; furthermore, Parc-Extension's population density is 34 times greater than Terrebonne. Of the 745 dissemination areas within the study area, 134 dissemination areas were absent of residential food gardens. To illustrate the distribution of residential food gardens, the following graphs showcase the number of residential food gardens across each territory (Figure 4.2).

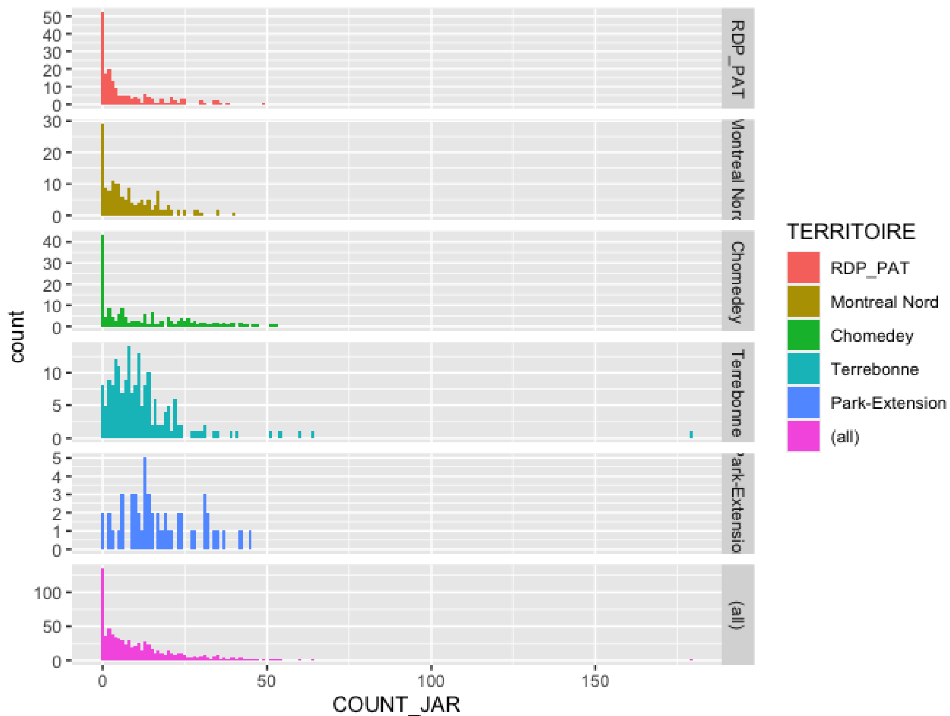


Figure 4.2 Distribution of residential food gardens across each territory

Although the absence of residential food gardens could be due to zoning limitations such as uses other than residential zones: commercial, industrial, and so on. Completing an analysis by lot or housing type could help clarify the absence of residential food gardens, as access to backyards in multi-storied buildings can be limited.

Table 4.1 Descriptive statistics for the number of residential food gardens across each territory

TERRITOIRE	Sum	Min.	Mean	Median	Max.	Sd
Terrebonne	2309	0	13	10	179	16
Chomedey	2330	0	14	8	53	14
RDP_PAT	1329	0	7	3	49	10
Montréal-Nord	1316	0	8	6	40	9
Parc-Extension	888	0	17	14	45	11
	8172					

Table 4.1 shows the number of residential food gardens in each territory. On average, Parc-Extension (median value of 14 gardens), Chomedey (8), and Terrebonne (10) have the greatest number of gardens by the dissemination area. Each territory had a dessemination area with no residential food gardens (minimum value of 0); as illusrtated in Figure 4.2 illustrating the distribution of residential food gardens across each territory. The territories with the highest number of residential food gardens were Terrebonne (maximum value of 179) followed by Chomedey (53). The remaining territories had a maximum of 40 to 50 residential food gardens per dissemination area. Similar to the maximum number of residential food gardens, Terrebonne and Chomedey had the greatest standard deviation (a value of 16 and 14 respectively), illustrating that the data sets were further away from the mean. Montreal-Nord had the lowest standard deviation (9), followed by RDP-PAT (10) and Parc-Extension (11). In the following sections, I will detail the description of gardens in each territory by looking at the density of gardens, the variation in size of gardens as well as spatial concentration of gardens.

4.2.2 Density of residential food gardens by territory

In Terrebonne, located off the island of Montreal, the concentration of residential food gardens was predominantly in the south-east and west corners of the territory. These areas were primarily occupied by residential housing (verified using Google satellite imagery, 2020). Although fewer residential food gardens were located in the north part of the territory, their absence or reduced concentration could be due to land use: 40% of the land-use in Terrebonne is agricultural (Reynaud, 2018).

In Chomedey, the density of residential food gardens was concentrated in the west part of the territory. It had a density of 35.0 gardens/km^2, significantly greater than

Terrebonne (10.0 gardens/km^2) and yet ten times lower than Parc-Extension. In RDP-PAT, the number of residential food gardens was concentrated in the south-west portion of the territory bordering Montreal Nord. RDP-PAT had the lowest density of residential food gardens (22 gardens/km^2) of the three territories located on the island of Montreal.

Montreal Nord presented a more even distribution of residential food gardens and had the second greatest density of the five territories' (83 gardens/km^2). Parc-Extension, the smallest of the five territories, had the greatest concentration of residential food gardens (522 gardens/km^2). Only two dissemination areas in Parc-Extension had an absence of residential food gardens; however, both were occupied by schools (verified using Google satellite imagery, 2020). Since each dissemination area's size is significantly different, and territories like Terrebonne may illustrate a more significant number of residential food gardens than in Parc-Extension, calculating the density provides a more accurate estimate of their presence.

4.2.3 Variation in size of residential food gardens by territory

Garden size varied throughout each territory (Figure 4.3). In contrast to the concentration of residential food gardens, gardens in Terrebonne, were greater in size in the northern outskirst of the territory (28 to 103 meters squared) and had a median value of 12.9 meters squared across the territory. A similar trend was observed in Chomedey, where the median size of residential food gardens was 19.9 meters squared, however, gardens greater in size (a range between 50 and 103 meters squared) were located on the outskirst of the territory. Gardens across RDP-PAT were on average above 16 meters squared with two dessemination areas containing gardens between 103 and 210 meters square, the largest residential food gardens in this study. However, both gardens overlapped into adjacent green spaces (see Figure 4.5). Montreal-Nord had the greatest median value of residential food garden across dessmination areas

(30.5 meters squared) and was relatively homogenous throughout the territory. Lastly, Parc-Extension had the smallest size of residential food gardens (median value of 6.4 meters squared).

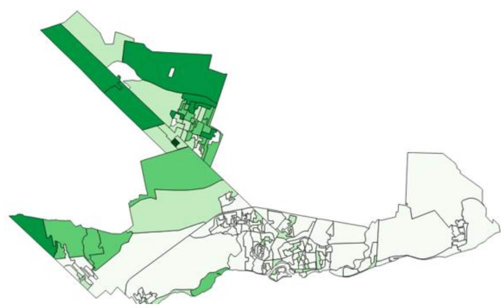
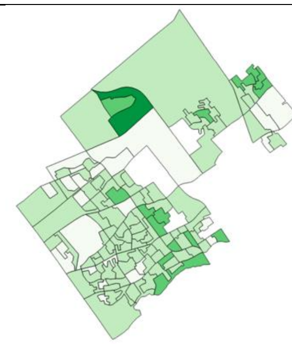
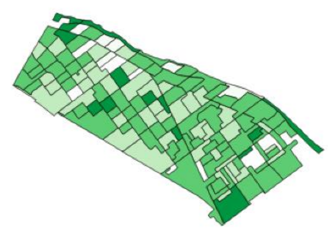
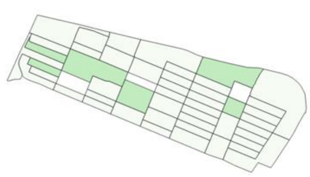
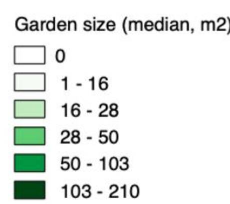
	
Terrebonne Size (median, mean): 12.39 m^2, 22.54 m^2	**Chomedey** Size (median, mean): 19.9 m^2, 26.33 m^2
	
RDP-PAT Size (median, mean): 26.5 m^2, 33.5 m^2	**Montreal Nord** Size (median, mean): 30.5 m^2 38.4 m^2
	
Parc-Extension Size (median, mean): 6.4 m^2, 9.4 m^2	

Figure 4.3 Spatial mapping of the median size of residential food gardens by dissemination area for each territory

Therefore, Table 4.3, illustrates the important difference in garden size across each of the five territories. Parc-Extension had the smallest gardens, while Montreal-Nord and RDP-PAT had the largest gardens. This was surprising as Chomedey and Terrebonne were considered as suburban territories, with a greater proportion of single-detached housing and therefore more space for residential food gardens. Table 4.2 summarizes the size of residential food gardens across each of the five territories.

Table 4.2 Descriptive statistics for the size (m^2) of residential food gardens across each territory

TERRITOIRE	**Sum** (tot area)	**Min.**	**Mean**	**Median**	**Max.**	**Sd**
Terrebonne	52051.00	0.00	22.54	12.39	643.70	37.10
Chomedey	61359.00	0.00	26.30	19.90	1072.50	41.40
RDP_PAT	44545.00	0.00	33.50	26.20	426.80	29.30
Montréal-Nord	50527.00	0.00	38.40	30.50	321.70	30.90
Park-Extension	8356.00	0.00	9.40	6.40	90.00	9.80
Total (m^2)	**216838.00**					
Total (ha)	**21.68**					

In total, Chomedey followed by Terrebonne, off-island suburban territories had the greatest area of residential food gardens (61 359 and 52 051 meters sqaured) as well as the largest garden size (maximum of 1072 and 643 meters squared) of the five territories within this study. As expected, Parc-Extension had the lowest total area of residential food gardens (sum of 8356 meters squared), followed by the smallest garden size (median value of 6.4 meters squared and a maximum value of 90 meters squared). RDP-PAT and Montreal-Nord had a total garden areas of 44 545 and 50 527 with similar size of residential food gardens (median value of 26.2 and 30.5 meters squared and a maximum value of 426.8 and 321.7 meters squared). Lastly, Parc-Extension had the lowest standard deviation (9.8) followed by RDP-PAT (29.3) , Montreal-Nord (30.9), Terrebonne (37.1) and Chomedey (41.4).

Furthermore, photos provided in Figures 4.4 – 4.6 illustrate the housing type and density in each of the five territories, along with the presence and size of residential food gardens.

Figure 4.4 Google-Earth screenshots of residential food gardens in Terrebonne (left) and Chomedey (City of Laval) (right).

As depicted in Figure 4.4, both Terrebonne and Chomedey had residential food gardens occupying backyards, and in some cases were the same size as in/above ground pools. Howevere, there was still a considerable amounts of space for residential food gardens in these neighbourhoods.

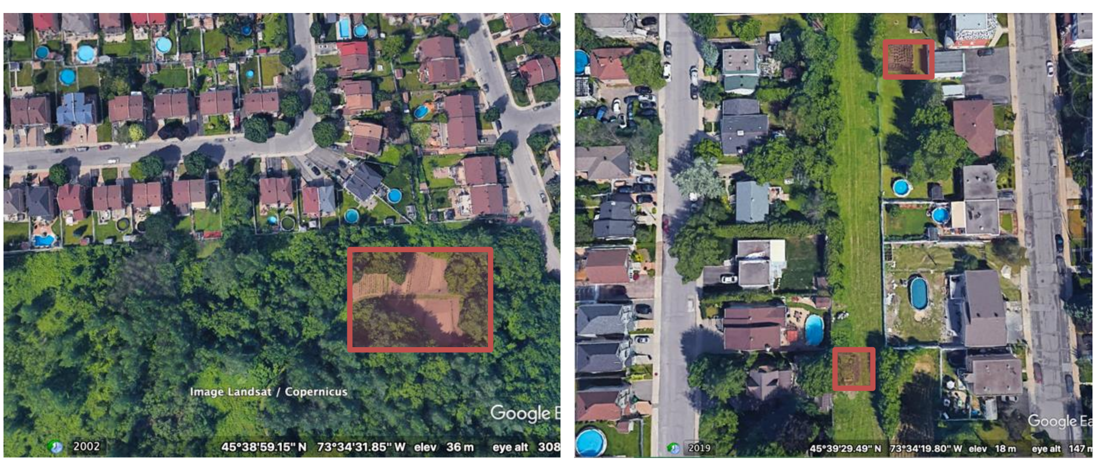


Figure 4.5 Google-Earth screenshots of residential food gardens in RDP-PAT.

Some of the largest residential food gardens were located in RDP-PAT as they extended into adjacent urban greenspaces. For example, in Figure 4.5, on the left, the residential food garden measured 210 m^2, the largest garden in this study.

4.6 Google-Earth screenshots of residential food gardens in Parc-Extension (left) and Montreal-Nord (right).

Photos illustrate the difference in the density of residential food gardens and the difference in back-yard size and housing type in Parc-Extension and Montreal-Nord. As depicted in the screenshots, Parc-Extension had a greater density of multi-storey housing and limited space for residential food gardens, while Montreal-Nord had a low housing and population density, and thus, had greater space available for residential food gardens (Figure 4.6).

4.2.4 Local Moran’s I: spatial concentration of food gardens

Chomedey and RDP-PAT had the greatest number of dissemination areas with a strong positive spatial autocorrelation followed by Terrebonne, Montreal-Nord and Parc-Extension. A strong positive spatial autocorrelation (high-high) indicated that dissemination areas with a high number of residential food gardens were surrounded by other dissemination areas with a high number of residential food gardens. Conversely, Chomedey followed by Terrebonne, RDP-PAT, Montreal-Nord, and Parc-Extension also had dissemination areas with strong negative autocorrelation (low-low), indicating that dissemination area without or having low numbers of residential food gardens were also clustered. Thus, the local Moran's I was able to identify spatial clustering of residential food gardens and absence of residential food gardens in each of the five territories. Few dissemination areas with a high number of residential food gardens were surrounded by dissemination areas with a low number of food gardens and vice-versa (high-low and low-high regions). The following table provides a summary of the results.

Table 4.3 Frequencies of dissemination areas with spatial autocorrelation across each territory

Territory	**Total # of DAs**	**Significant DAs (high-high)**	**Significant DAs (high-low)**	**Significant DAs (low-low)**	**Significant DAs (low-high)**	**Not significant**
Terrebonne	181	11.6%	0.5%	18.2%	6.6%	62.9%
Chomedey (City of Laval)	173	27.7%	0.0%	26.6%	0.0%	45.7%
Montreal-Nord	155	0.6%	0.6%	10.3%	3.2%	76.1%
RDP-PAT	185	19.5%	1.6%	10.8%	2.7%	65.4%
Parc-Extension	51	5.8%	1.9%	5.8%	7.8%	78.4%

**DAs – dissemination area*

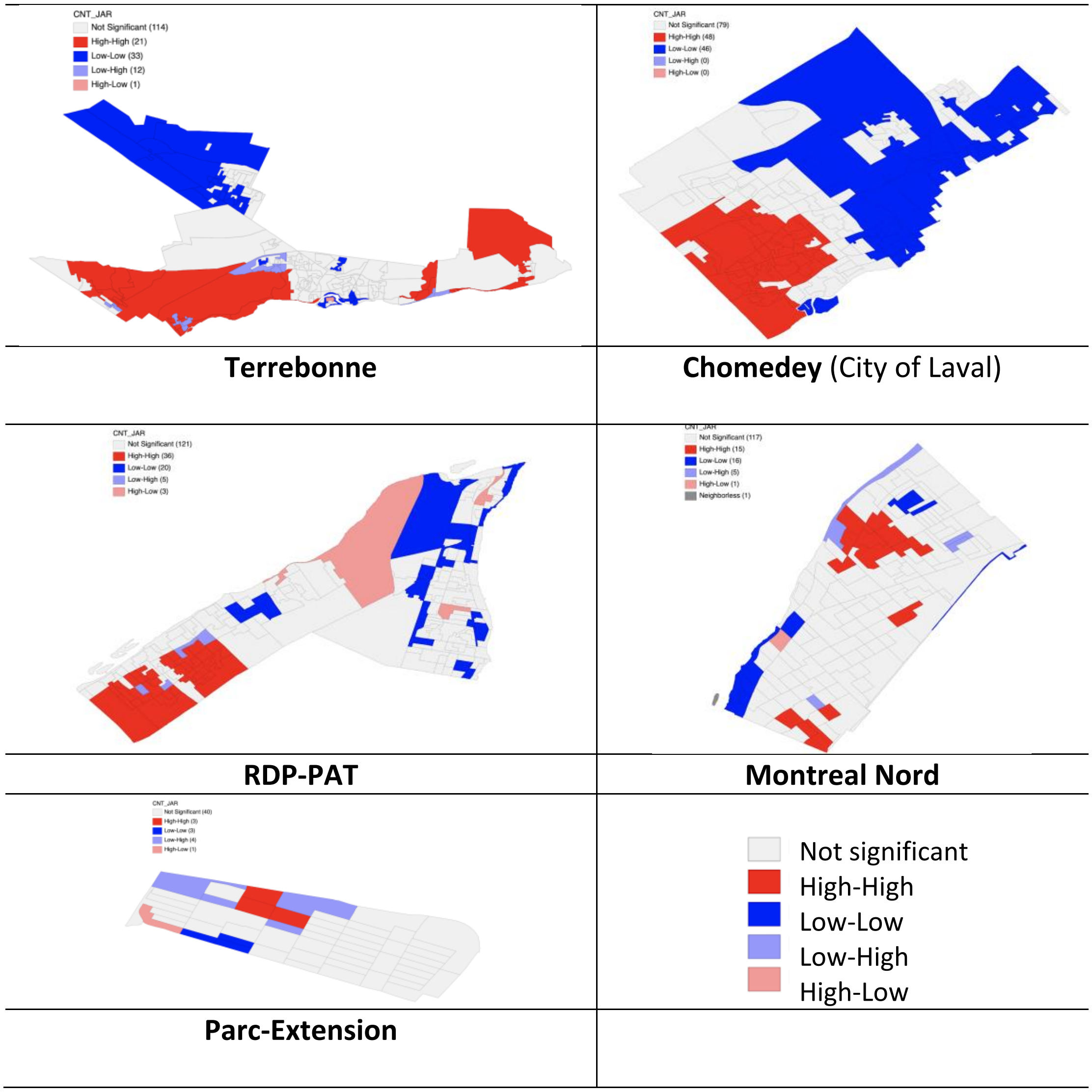


Figure 4.7 Local Moran’s I, spatial autocorrelation across each territory

Spatial clustering of residential food gardens followed similar trends observed in the concentration of residential food gardens (Figure 4.7). Off-island territories (Terrebonne and Chomedey) had larger and more distinct clusters in comparison to on-island territories (Montreal-Nord, RDP-PAT and Parc-Extension). In Terrebonne, the majority of the dissemination area had non-significant spatial autocorrelation (62.9%).

However, high-high and low-low clusters did exist (11.2% and 18.6%) in the southern and northern sectors of the territory. This confirmed that dissemination areas with a similar phenomenon, and in this case the presence of residential gardens, resembled. However, in areas with high-low or low-high spatial autocorrelation, the presence of residential food gardens could not explain the clustering of these dissemination areas.

In Chomedey , spatial clustering formed two distinct areas: dissemination areas with residential food gardens clustered on the eastern side of the territory (high-high, representing 27.7% of the dissemination areas) and dissemination areas without residential food gardens clustered on the western side of the territory (low-low, representing 26.6%). This phenomenon could be due to zoning, as residential housing is located primarily in the eastern part of the territory. The remaining dissemination areas were non-significant (45.7%).

Of the five territories RDP-PAT followed Parc-Extension, and Montreal-Nord had the lowest proportion of high-high (19.5%, 5.8%, 0.6%) and low-low (10.8%, 5.8%, 10.3%) spatial autocorrelation. Although high-low and low-high spatial autocorrelation occurred in each of the five territories except Chomedey, these areas demonstrated that other underlining spatial processes could explain the spatial clustering of these dessemination areas. However, these areas of spatial clustering attained a maximum of 8% in Parc-Extension.

4.3 Modeling the effects of population profiles across the dissemination areas

The following statistic models were aimed to decipher the influence of population profiles on the presence of residential food gardens across the dissemination areas. Furthermore, it identified the most appropriate statistic model for the remainder of the modelling analysis.

4.3.1 Model 1: Fixed-effects negative binomial regression model

The generalized linear model was fitted (*glm* function in R-Studio 1.2.5) for a Poisson distribution. Fixed-effects provided a global outlook on the relationship between the dependent variable (number of residential food gardens) and the 21 independent variables (the density, socio-economic and ethnocultural variables). Model 1 presents the results for the Poisson model (Table 4.4).

Of the 21 independent variables, 14 had a p-value lower than 0.001(as per the mixed regression model run in R-studio), indicating that they were significantly associated with the number of residential food gardens. However, the high AIC value (8288) suggested that the model was not very robust. Furthermore, the over distribution function demonstrated that the count values for the number of residential food gardens were overdispersed; the number of dissemination areas with no residential food gardens was too high. Therefore the variance was not proportional to the mean. A fixed negative binomial model was then used for the remainder of the statistical analysis to account for the overdispersion.

4.3.2 Model 2: Fixed-effects negative binomial regression model

As illustrated in Model 2 (Table 4.4), a generalized linear model (*glmer* function in R-Studio 1.2.5) fitted for a fixed negative binomial had a significantly lower AIC value (4830) in comparison to Model 1 (8288), demonstrating increased model robustness. Similar to Model 1, 14 socio-economic variables were identified as significant (p-values equal to 0).

Using a negative binomial model accounted for the over-dispersed count data of the residential food gardens. It had an overdispersion value near 1, indicating that the variance was proportional to the mean (ratio = 0.94). The r squared marginal and conditional values were calculated as an additional model robustness test and indicated that the model represented 21% of the residential food garden variance. Both the conditional and marginal r squared values were equal as the model was only run for fixed effects.

Population density had a significant negative association with the number of residential food gardens, while social stratification variables had a predominantly positive correlation, except for those concerning age. Ethnocultural variables had a predominantly negative correlation except for immigrant populations from South Asia, the Middle East and the Mediterranean.

Table 4.4 Comparison of fixed-effect Poisson and negative binomial regression models

	Model 0 (Null)		**Model 1**		**Model 2**	
	Fixed Poisson		Fixed Poisson		Fixed Negative Binomial	
	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
(Intercept)	2.39	***	2.55	***	2.67	***
Urban form						
POP_DEN_1000			-0.02	***	-0.03	***
Social Strat.						
PCTINAF_Less20			0.03	***	0.03	***
PCTINAF_80_More			0.03	***	0.03	***
PCTEDU_UN_AB			0.00		0.00	
PCTTOT_OWN_10			0.11	***	0.12	***
PCT_CAN_10			0.00		-0.01	
PCTAGE_20_34			-0.04	***	-0.04	***
PCTAGE_35_49			0.00		0.00	
PCTAGE_50_64			-0.05	***	-0.04	***
PCTAGE_65_OV			-0.02	***	-0.03	***
Ethnocultural						
South_Asia			0.04	***	0.05	***
East_Asia			0.00		0.00	
Middle_East			0.02	***	0.02	***
North_Africa			-0.01	***	-0.01	***
Western_Europe			0.00		-0.02	
Mediterranean_Europe			0.05	***	0.07	***
South_Western_Europe			0.01		0.00	
Central_Europe			-0.07	***	-0.09	***
Latin_America			-0.03	***	-0.03	***
Caribbean			-0.01	***	-0.01	***
AIC	11670		8288.00		4830.00	
Overdistribution fucntion	15.21		8.81		0.94	
R-squared[t]						
Marginal	0		0.82		0.21	
Conditional	0		0.82		0.21	
McFadden pseudo r-squared			0.29		0.29	
Number of territories	5.00		5.00		5.00	
Number of observations	745.00		745.00		745.00	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

[t]trigamma values

4.3.3 Model 3: Mixed negative binomial regression model

Using a mixed-negative binomial regression model, the following models (3a through 3d) tested the probability of the count of residential food gardens as a function of the population density, socio-economic and ethnocultural variables integrated within each model, and how the intercept varied across each territory. Therefore, enabling the prescence of residential food gardens to vary by the independent variables and also by territory (Harrison et al. 2018). The following table (Table 4.5) provides a summary of the mixed negative binomial regression model.

Table 4.5. Mixed-effects for the negative binomial regression model

	Model 3a Mixed Negative Binomial - null model		Model 3b Mixed Negative Binomial					Model 3c Mixed Negative Binomial					Model 3d Mixed Negative Binomial				
	Coef.	Sig.	Coef.	Sig.	IRR	IRR_LL	IRR_UU	Coef.	Sig.	IRR	IRR_LL	IRR_UU	Coef.	Sig.	IRR	IRR_LL	IRR_UU
(Intercept)	2.41	***	2.22	***	9.19	3.04	27.79	1.63	***	5.11	3.09	8.45	1.70	***	5.48	2.43	12.38
Urban form																	
POP_DEN_1000			-0.49	***	0.95	0.93	0.98						-0.05	***	0.95	0.93	0.97
Social Strat.																	
PCTINAF_Less20_10			0.45	***	1.57	1.36	1.81						0.16	**	1.18	1.04	1.33
PCTINAF_80_More_10			0.59	*	1.81	1.14	2.88						0.50	*	1.65	1.12	2.43
PCTEDU_UN_AB_10			-0.23	*	0.79	0.65	0.96						-0.17	.	0.84	0.71	1
PCTTOT_OWN_10			0.20	***	1.22	1.16	1.28						0.12	***	1.13	1.08	1.17
PCTAGE_20_34_10			-0.37	**	0.69	0.54	0.89						-0.13		0.88	0.72	1.06
PCTAGE_50_64_10			-0.54	***	0.58	0.48	0.71						-0.23	**	0.79	0.67	0.93
Ethnocultural																	
South_Asia								0.26		1.03	0.99	1.07	0.18		1.2	0.81	1.75
Middle_East								0.74	***	1.08	1.04	1.11	0.59	***	1.81	1.33	2.45
North_Africa								-0.04		1.00	0.97	1.02	0.01		1.01	0.8	1.27
Western_Europe								-0.04		0.96	0.89	1.04					
Mediterranean_Europe								0.10	***	1.11	1.09	1.12	0.86	***	2.36	2.06	2.72
South_Western_Europe								0.05		1.05	0.98	1.13					
Latin_America								-0.43	*	0.96	0.98	1.01	-0.38	*	0.68	0.48	0.97
AIC	5060.00		4916.00					4832.00					4743.00				
Overdistribution fucntion	0.90		0.95					1.12					1.07				
ICC																	
Adjusted	0.09		0.35					0.28					386.00				
Conditional	0.09		0.23					0.17					0.21				
R-squared[t]																	
Marginal	0.00		0.20					0.25					0.33				
Conditional	0.03		0.34					0.36					0.49				
McFadden pseudo r-squared			0.03					0.05					0.00				
Singularity	0.30		0.63					0.51					0.62				
Number of observations (DA's)	745.00		745.00					745.00					745.00				
Number of territories	5.00		5.00					5.00					5.00				

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

[t]trigamma values

Model 3a: mixed negative binomial null model

First, model 3a tested the distribution of the variance for the count of residential food gardens without the integration of the independent variables. In comparison to model 3b, 3c, and 3d, model 3a explains low variance of the count of gardens (r-square condition value being 3%). In comparison to model 3b (34%), model 3c (36%) and model 3d (49%), the r-squared conditional value as well as the lower AIC (refer to Table 4.6) value, confirms that the model becomes more robust as independent variables are integrated. In essence, the null model provided a means of comparison for the explanation of the variance of residential food gardens.

Model 3b: mixed negative binomial model – social stratification variables

Model 3b illustrated the associations between residential food gardens, population density and social stratification factors. The ICC conditional value demonstrated that the associations between the independent and dependent variables varied amongst the five territories as the value was closer to zero (0.23). Thus, indicating that there was a low similarity amongst the grouping of variables. In otherwords, the influence of population density and social stratification variables had varying relationships with the count of residential food gardens between and across each of the five territories.

All seven of the variables were significant, with p-values ranging from 0 to 0.05. Of the seven significant variables, the association between residential food gardens and population density was negative, suggesting that the higher the population density, the fewer gardens there are. Among the variables included in the social stratification, age and education were negatively associated with gardens and the two income brackets and ownerships were positively associated with the presence of residential food gardens.

Furthermore, population density also had a slightly lower effect on the number of residential food gardens, as the incident rate ratio decreased by a factor of 0.95 for every unit increase of population density. In comparison, an increase of one unit of the percentage of people earning less than $20,000 per year, the incident rate ratio for the number of residential food gardens increased by a factor of 1.57. The percentage of citizens earning greater than $80,000 per year had the greatest probability: for every one unit increase, the incident rate ratio for the number of residential food gardens increased by a factor of 1.81. Citizens with an education above a university diploma had a one unit incident rate ratio increase for the number of residential food gardens by a factor of 0.79. For an increase of one unit of the percentage of homeowners, the incident rate ratio for the number of residential food gardens increased by a factor of 1.22. Lastly, the percentage of citizens between the ages of 20 and 34 as well as 50 and 64 had a lower incident rate ratio. For every unit increase, the incident rate for the number of residential food gardens increased by a factor of 0.69 and 0.58, respectively.

Model 3c: mixed negative binomial model – ethnocultural variables

Model 3c only included the seven ethnocultural variables, of which three were significant. The ICC conditional value was closer to 1 (0.17), indicating that the relationship between the dependent and independent variables varied amongst the five territories and had a greater variance than in model 3b (ICC value of 0.23). Furthermore, model 3c was more robust than model 3b, as the AIC value was 4832 in comparison to 4919. As lower AIC values indicate greater model robustness, it can be concluded that the ethnocultural variables could better exaplain the variation of the number of residential food gardens across each of the five territories.

In comparison to the social stratification variables, the incident rate ratio for the three significant ethnocultural variables was slightly lower. For an increase in one unit of the percentage of immigrants from the Middle East and Mediterranean Europe, the incident rate ratio was increased by a factor of 1.08 and 1.11, respectively. However, for a one-unit increase in the percentage of immigrants from Latin America, the incident rate ratio diminished by a factor of 0.96.

Model 3d: mixed negative binomial model – all variables

The final model (3d), included all the variables and was the most robust model. It had an AIC value of 4743 which is the lowest of the three models. Similar to trends illustrated in models 3b and 3c, the ICC conditional value indicated that the relationships amongst the independent variables and the number of residential food gardens were disimilar across the five territories (ICC conditional was a value of 0.21).

The overdistribution function was similar to the two proceeding models, with a value of 1.07, indicating that the variance was proportional to the mean. The r-squared conditional value, which evaluates the model's robustness for both fixed and random effects, was 49%. Thus, our final mixed-effects negative binomial regression model provides the greatest explanation for the variance of residential food gardens across the five territories compared to Model 3b with an r-squared conditional value of 34% and Model 3c with an r-squared conditional value of 36%.

In Model 3d, population density remained consistently significant with a negative relationship with the number of residential food gardens. For every unit increase of population density, the incident rate ratio increased by a factor of 0.95. Thus, an increase in population density has an overall negative effect on the presence of residential food gardens. For the social stratification variables, five of the six variables remained significant, with the percentage of homeownership with the greatest significance, followed by the percentage of citizens earning less than $20,000 per year after-tax, the percentage of persons between the age of 50 and 64, the percentage of citizens earning more than $80,000 per year after-tax and the percentage of citizens with a university degree or above.

The incident rate ratio was greatest for the percentage of citizens earning $80,000 per year after-tax, followed by the percentage of citizens earning $20,000 per year after tax and the percentage of homeowners. Thus, for every one unit increase, the incident rate ratio increased by a factor of 1.65, 1.18 and 1.13, respectively. Although homeownership had the greatest significance of the social stratification variables, exposure to this variable had a lower probability of the presence of residential food gardens, as the incident rate ratio for every unit increase was raised by a factor of 1.13, slightly lower than the other 3 sigificant social stratification variables. For the remaining social stratification variables, including the percentage of citizens with a university degree or greater and the percentage of citizens between the ages of 50 and 64, for every one unit increase, the incident rate ratio decreased by a factor of 0.84 and 0.79.

For the ethnocultural variables, the three significant variables remained consistent compared to the previous models. The percentage of citizens with a place of birth from Latin America had a negative relationship with the number of residential food gardens. For every one-unit increase in the percentage of citizens from the Middle East, the number of residential food gardens rose by a factor of 1.81. In comparison to Model 3c, the incident rate ratio for a one-unit increase in the percentage of citizens from the Middle East was lower (incident rate ratio of 1.08). For every one unit increase in the percentage of citizens from Mediterranean Europe, the incident rate for the number of residential food gardens increased by a factor of 2.36, thus, greater than Model 3c (incident rate ratio of 1.11). Lastly, for the percentage of citizens from Latin America, the incident rate for the number of residential food gardens diminished by a factor of 0.68.

Model 4: negative binomial regression model -random effects of five independent variables

Of the nine significant variables in Model 3d, five had varied relationships across each of the five territories. I then conducted five models with these five variables randomly varying across the territoires (models 4a to 4e). Table 4.6. presents results of these models.

Table 4.6 negative binomial regression models – fixed effects of five independent variables

	Model 4a: Population density		**Model 4b:** Citizens earning less than $20,000		**Model 4c:** Citizens earning more than $80,000		**Model 4d:** Citizens with a universiry or greater		**Model 4e:** Homeowners	
	Mixed Negative Binomial - all significative variables		Mixed Negative Binomial - all significative variables		Mixed Negative Binomial - all significative variables		Mixed Negative Binomial - all significative variables		Mixed Negative Binomial - all significative variables	
	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
(Intercept)	1.64	***	1.60	***	1.81	***	1.71	***	1.70	***
Urban form										
POP_DEN_1000	-0.85	**	-0.05	***	-0.05	***	-0.05	***	-0.05	***
Social Strat.										
PCTINAF_Less20_10	0.18	**	0.17	*	0.15	*	0.15	*	0.16	**
PCTINAF_80_More_10	0.43	*	0.51	**	0.02		0.35	.	0.50	*
PCTEDU_UN_AB_10	-0.19	*	-0.18	*	-0.15	.	-0.14		-0.17	.
PCTTOT_OWN_10	0.11	***	0.12	***	0.12	***	0.12	***	0.12	***
PCTAGE_20_34_10	-0.11		-0.12		-0.13		-0.14		-0.13	
PCTAGE_50_64_10	-0.22	**	-0.22	**	-0.23	**	-0.23	**	-0.23	**
Ethnocultural										
South_Asia	0.13		0.14		0.15		0.26		0.18	
Middle_East	0.57	***	0.59	***	0.62	***	0.64	***	0.59	***
North_Africa	0.05		0.00		-0.03		0.01		0.01	
Mediterranean_Europe	0.88	***	0.85	***	0.85	***	0.85	***	0.86	***
Latin_America	-0.34	.	-0.38	*	-0.41	*	-0.37	*	-0.38	*
AIC	4726.00		4744.00		4740.00		4738.00		4745.00	
Overdistribution fucntion	1.05		1.07		1.06		1.07		1.07	
ICC										
Adjusted	0.20		0.38		0.42		0.24		0.36	
Conditional	0.08		0.21		0.23		0.12		0.20	
R-squared[t]										
Marginal	0.42		0.32		0.32		0.35		0.30	
Conditional	0.59		0.51		0.52		0.48		0.44	
Singularity	0.53		0.09		0.67		0.25		0.00	
Number of observations (DA's)	745.00		745.00		745.00		745.00		745.00	
Number of territories	5.00		5.00		5.00		5.00		5.00	

Citizens between the ages of 20 and 34 as well as those with a South Asian or North African background were not significant in each of the five models (model 4a throuh 4e). Model 4a with the population density varied across the territories had the lowest AIC value (4726) of all the models run throuhout this study. Furthermore, as indicated by the conditional r-squared value, model 4a explained 59% of the variance of residential food gardens.

However, the two variables that changed their relationship with the number of residential food gardens across the territories were the percentage of the population earning $80,000 or greater after-tax and those with a university degree or above. More specifically, for the percentage of citizens earning $80,000 or greater after-tax (PCTINAF_More80_10), the relationship was negative in Chomedey and RDP-PAT. Conversely, the relationship was positive in Terrebonne, Parc-Extension and Montreal-Nord.

For the percentage of citizens with a university degree or greater (PCT_UN_AB_10), Terrebonne and RDP-PAT had a positive relationship, while Chomedey, Parc-Extension and Montreal-Nord had a negative relationship with the number of residential food gardens. Although the intercept varied for the relationship between residential food gardens and population density across each territory, it reamined negative. Lastly, for the percentage of citizens earning less than $20,000 after-tax and the percentage of homeowners both varied, but had a positive relationship with the number of residential food gardens across each territory (Table 4.7).

Table 4.7. Random-effects negative binomial regression model

RDP-PAT	**POP_DEN_1000**		**PCTiNAF_less20_10**		**PCTINAF_More80_10**		**PCT_UN_AB_10**		**PCTTOT_OWN_10**	
Territories	Coef.	IRR	Coef.	IRR	Coef.	IRR	Coef.	IRR	Coef.	IRR
Terrebonne	-0.104745	0.90055413	0.22909	1.2574552	0.01857	1.01874349	-0.339	0.71248245	0.1184	1.1256943
Chomedey	-0.06065	0.94115259	0.17216	1.18786788	-1.02884	0.35742133	-0.2929	0.74609675	0.1187	1.12603206
RDP-PAT	-0.003388	0.99661773	0.25454	1.28986815	-0.10756	0.89802264	0.1144	1.12120052	0.1181	1.12535664
Montréal-Nord	-0.115739	0.89070767	0.11558	1.12252431	0.45521	1.57650441	-0.3135	0.73088438	0.1173	1.12445672
Parc-Extension	-0.139114	0.87012883	0.07881	1.08199872	0.80926	2.24624515	0.155	1.16765796	0.1186	1.12591946

4.4 Summary

Results illustrate that population profiles do have an influence on the number of residential food gardens within and across the five territories in the MMC area. The mixed negative binomial model containing, with population density varied across the territories (model 4a) was the most robust model of all models run throughout this study as it had the lowest AIC value (4726), and the conditional r-squared indicated that the model represented 59% of the variance of residential food gardens.

The relationship amongst the independent variables and the number of residential food gardens remained consistent throughout each model with the percentage of citizens between the ages of 50 and 64, citizens from Latin American and population density with a negative relationship with the number of residential food gardens. Furthermore, population density, the percentage of homeowners, and citizens from Mediterranean Europe and the Middle East had the most significant relationship with the number of residential food gardens throughout each model. Among the social stratification variables, positive associations were found for the percentage of citizens earning greater than $80,000 or less than $20,000 greater after-tax, as well as homeownership with an incident rate ratio value of 1.65, 1.18 and 1.13, respectively.

Lastly, using the random effects negative bionimal regression model identified five variables that had a changing influence on the number of residential food gardens, i.e. the percentage of citizens earning more than $80,000 after-tax and those with a university degree experienced a variation in their positive or negative relationship with the number of residential food gardens. In contrast the percentage of homeowners, citizens earning less than $20,000 after-tax and population had consistent positive or negative relationships with the number of residential food gardens. Therefore, evaluating the influence of population profiles at the territory level (micro) enables a more in-depth understanding of the spatial patterns of urban agricultural activities and indicates that the relationship between the number of residential food gardens and the population profile can vary across locales. In the next chapter I will discuss these findings by comparing with previous studies and situating them in broader perspectives.

CHAPTER V

DISCUSSION

5.1 Introduction

The following chapter will discuss the results from the spatial analysis and multi-level regression models used to better understand the relationships between the number of residential food gardens and population profiles. Furthermore, it will analyze and compare with previous studies in North America and Europe. Finally, the chapter will provide recommendations on how to best support and further engage individuals and communities' in urban agricultural activities.

5.2 Spatial variations of residential food gardens

5.2.1 Prevalence and clusters of residential food gardens

Residential food gardens significantly contribute to the urban food production landscape, as their presence greatly outnumbers other forms of urban agriculture, such as community, allotment, or school gardens. We show that with over 8000 gardens identified over five territories in this study, with the size and distribution of residential food gardens significantly varied throughout each territory. This result was mirrored in other recent studies evaluating the presence of residential food gardens (McClintoclk et al. 2016; Smith et al. 2013; Taylor & Lovell 2012) and validates their importance as an urban food production resource.

More specifically, Chomedey (City of Laval), followed by Terrebonne, both suburban territories located off the island of Montreal, had the greatest number of residential food gardens. This trend was contrary to the results found in Portland, OR, (McClintock et al. 2016), where the greatest number of gardens were found in the urban versus suburban communities. As illustrated in table 5.1, Portland's population density is significantly lower than the MMC area. Comparing the density and number of residential food gardens with other recent studies such as in Chicago, IL (Taylor and Lovell 2012) must also take into consideration the size and density of the city.

Table 5.1 Comparing population densities across other North American metropolitan areas renowned for urban agriculture activities

Metropolitan area	Population	Population density (persons/km^2)	Source
Portland, OR (USA)	2,232,607	129	McClintock et al. (2016), pg.4
Chicago, IL (USA)	2,718,555	4,618	Census Bureau (2018) Taylor & Lovell (2012)
Montreal, QC (Canada)	4,098,927	890	Statistics Canada (2017)

Concerning the spatial distribution of residential food gardens, in Taylor & Lovell (2012), residential food gardens were unevenly distributed, with densely-populated neighbourhoods virtually devoid of gardens. In Montreal, Pham et al. (2013) found less residential vegetation in urban territories; however, greater tree and shrub cover. Although comparisons with previous studies do not clarify whether residential food gardens are predominantly in urban versus suburban communities, their distribution is not homogenized within and across territories. In studies evaluating other forms of urban vegetation such as urban street tree cover (Pham et al. 2017), or urban green infrastructure (Wang et al. 2019), these socio-environmental assets have been attributed to more affluent communities. As residential food gardens respond to several socio-economic and environmental challenges of the 21st century, ensuring equitable distribution is crucial to provide all individuals and communities with access to these resources. Although it is difficult to achieve equitable access to houses with space available for gardening, it is important to implement other forms of food gardens (e.g. community or school gardens) in neighbourhoods having fewer residential gardens or limited access.

Local spatial autocorrelation using local Moran's I showed that spatial clustering and outliers occurred throughout each territory. Surprisingly, however, in Parc-Extension, where there was a significant density of residential food gardens, few dissemination areas were significant and had a positive and strong spatial autocorrelation. With a median of 14 residential food gardens per dissemination area (refer to Table 4.2), the highest of the five territories, almost 80% of the dissemination, were not significant (Figure 4.7). A possible explanation, could be due to the low number of dissemination areas and the size of the territory. With a total of 51 dissemination areas in Parc-Extension, it is the minimum number of "*n*" values required for a statistic analysis (d'Astous and Daghfous 2011).

Chomedey (City of Laval) and RDP-PAT had the most significant number of dissemination areas and the greatest number of spatial clusters of residential food gardens. Both neighbourhoods are urban, located on the island of Montreal and resemble in their population profiles: a high percentage of property owners, population density and so on (refer to Table 3.2). However, Chomedey (City of Laval) has a greater number of residential food gardens per kilometre squared. In Terrebonne, significant dissemination areas were located in dissemination areas with greater annual income and a higher percentage of property owners. On the furthest east and west sectors of the territory, 21 dissemination areas had a strong positive spatial autocorrelation. A large cluster of dissemination areas without residential food gardens was located in the northern part of the territory furthest from the downtown core and closer to the agricultural zone. Compared to Portland, OR, McClintock et al. (2016) also completed a univariate Local Moran's I for the presence of residential food gardens. Their results indicated clustering of residential food gardens in both front and backyards. Although the spatial cluster patterns were dispersed differently in Portland, OR versus Vancouver, WA, the Local Moran's I analysis confirmed that there was a "tendency for similar phenomenon to be spatially related" (McClintock et al., 2016). Therefore, spatial autocorrelation in the five territories within this study confirm that dissemination ares with similar phenomenon are spatially clustered. One explanation for spatial autocorrelation is that as citizens and communities become invested in their neighbourhood, their actions are observed by felllow neighbours and friends who are then also driven to participate in projects that provide benefits for individuals and community memebers (Hunter and Brown 2012).

5.2.2 Variation in garden size

Garden size was greater in suburban versus urban territories, which can be explained by the urban form. Several studies have found that the variation in garden size can be attributed to factors, such as population density and housing type; differences between detached/semi-detached housing such as in the city of Sheffield, UK (Smith et al. 2005) or the presence and connectivity of urban green infrastructure in Leipzig, Germany (Wang et al. 2019). Lot size (Smith et al., 2005) and environmental conditions such as tree canopy (Kirkpatrick et al., 2007), as well as individual's access to socio-economic resources including income, materials and time, were also important factors found to contribute to the size of residential food gardens (Nogeire-McRae et al. 2018; Tratalos et al. 2007).

Our results confirm that smaller gardens were located in urban territories such as Parc-Extension (median garden size of 6.4 meters squared), and larger gardens were situated in urban territories further from the downtown-core such as Montreal-Nord (median garden size of 30.5 meters squared) or suburban territories including Chomedey and Terrebonne (median garden size of 19.9 and 12.39 meters squared) . Although the location was not a determining factor of garden size throughout the literature, the average size of residential food gardens ranged between 6 to 30 meters squared across the five territories, which was comparable to recent studies: a median of 15.61 meters squared in Santa Clara County, CA (Diekmann, Gray, and Baker, 2018), between 9.3 and 46.5 meters squared in Portland, OR (McClintock et al. 2016) and an average of 15.7 to 66.6 meters squared for residential food gardens in Chicago, IL (Taylor and Lovell 2012). Furthermore, residential food gardens located on the fringes of green spaces, parks, or hydro lines were significantly greater in size: often over 100 meters squared. This trend occurred in each territory in this study, except for Parc-Extension.

Although garden size does not directly impact total food production, as it can depend on the diversity of vegetables planted, as well as gardening practices (Kirkpatrick and Davison 2018), the available potential space for food gardens impacts the capacity for individuals and communities to become more food self-sufficient. McClintock et al. (2016) in Portland, OR, reported that residential food gardens fulfilled 10 to over 50% of total vegetable needs during the growing season. Furthermore in City of Mississauga (Ontario, Canada) homeowners living in single-detached housing with larger lots had a greater probability of having a residential food garden (Conway and Brennan 2014).

However, it is to nuance that vegetable consumption can range amongst socio-economic demographics; lower-income groups were found to consume vegetables between once and twice per week, while higher-income groups consumed vegetables daily (McClintock et al. 2016). Although there is a trend that households with residential food gardens have increased total vegetable consumption, Algert et al.'s (2016) empirical study in San Jose, CA suggests that home gardening not only doubles vegetable consumption during the growing season but can reduce fast-food consumption, motivate gardeners to make healthier food choices, while growing and preserving cultural identity and food scholarship. Therefore, the size of residential food gardens can significantly contribute to the health and wellbeing of individuals as well as contribute to the livability and resilience of cities.

The cost and time associated with residential food gardens cannot be ignored, especially when the garden is large. Even if individuals have access to space, the time and money required may limit their ability to construct and maintain a garden. For example, depending on where seeds are purchased and the proportion of upcycled building materials utilized, a 9.3 square meter raised garden-bed can cost upwards of $270.00 US in Fort Collins, Colorado (Nogeire-McRae et al., 2018, pg. 752). In the City of Guelph, located southwest of Toronto, ON, Canada, CoDyre et al. (2015) found that gardeners would need to invest 3.5 weeks of full-time labour to harvest enough vegetables for an entire year. Furthermore, this does not include the time required to process and transform vegetables into condiments or other food products.

Lastly, whether all individuals living within a household have access to the front and backyard can depend on the housing type and the property owner (Diekmann et al. 2018). As urban territories (Parc-Extension and Montreal-Nord) had greater proportions of renters and higher-density housing types (duplex's and buildings under five stories), these communities could face greater challenges in accessing land for food gardening. Therefore, access to space is the greatest constraint of residential food gardens, along with ideal growing conditions such as sunlight and access to water that may be limited depending on where the garden is located on the property. Furthermore, the time to manage and process harvested goods require a significant amount of effort and knowledge (Taylor and Lovell 2012).

In summary, our spatial analysis demonstrated that residential food gardens are unevenly distributed throughout the study area, with a greater density of gardens located in the urban territories. Although the garden size was greater in suburban versus urban territories, more data is required to discern the production capacity of these gardens, their use, and the types of urban gardening practices.

5.3 Influence of social stratification on the extent of residential food gardens

To further understand the socio-spatial processes underlying the distribution of residential food gardens, a multi-level regression model was devised to evaluate the influence of socio-economic factors on the number of residential food gardens across and between the five territories. Of the social stratification variables tested within each model, homeownership, income, and education, were the strongest predictors of residential food gardens. Homeownership having the greatest influence over the presence of residential food gardens, highlights the inequitable access to food production at the household level. This result was not surprising, as similar results were found in McClintock et al. (2016) study in Portland, OR and Smith et al. (2013) study in Madison, WI. In addition, Taylor and Lovell (2012) study in Chicago, IL, found high concentrations of residential food gardens in “newer, owner-occupied single-family detached houses” (pg. 64). A common explanation is that homeownership provides an incentive for individuals to invest in their property and have the freedom to determine how their land will be used (Diekmann et al. 2018; McClintock et al. 2016).

Housing age and the number of years citizens occupy a household can augment the complexity and age of shrubs, trees and other urban vegetation including food gardens (van Heezik et al. 2013). Whether these gardens are used as a means of food security or for other reasons: environmental, educational, pleasure, our study does not evaluate the motivations or total vegetable yield at the household level.

The influence of income levels on the number of residential food gardens also needs to be further investigated. Our results showed polar significance, with individuals earning below $20,000 after-tax and above $80,000 after-tax having the greatest influence. An income gap representing middle-class individuals was not significant within this study. Comparing with prevIsous studies, in the state of Ohio, vegetable gardens were highly correlated with those facing economic hardship (earning less than $35,000 US per year), and thus were used as a food self-provisioning strategy (Schupp and Sharp 2012). In Darby et al., (2020) low-income individuals were most often motivated to have a garden to save money, for pleasure, being outdoors, and to spend time with friends and neighbours as well as spirituality. They also outlined the importance of cultivating culturally appropriate food. In contrast, households facing economic hardship were also least likely to participate in residential food gardens, due to financial and time restraints as well as access to space (Darby et al., 2020). Gardening may also be used as a source of income for new immigrant populations as found in Malmö, Sweeden (Hochedez, 2018). Although our results also shown the significant influence of homeownership and other economic factors that are linked to more affluent communities. Although income levels below $20,000, after-tax also had a considerable impact, a qualitative analysis is required to understand the motivations of these gardeners.

Furthermore, Darby et al., (2020) stated that the social benefits of gardening "extend beyond [the] sharing food to sharing information and experiences" (Darby et al., 2020, pg. 64). Thus, contributing to the evolution and value of what Buchmann, (2009) calls traditional ecological knowledge. With residential food gardens located throughout cities, they become what Barthel et al. (2014) call 'pockets' of socio-ecological memory, storing "knowledge and experience required to grow food" (pg.145) throughout urban landscapes.

5.4 The impacts of culture, education and age on the prevalence of residential food gardens

Impacts of ethnoculture

Throughout the literature, studies focusing on who participates in residential food gardens have often focused on differences in income level, education, age, and geographical location (McClintock et al., 2016). As demonstrated throughout this study, ethnocultural background can also play an important role in the motivations of residential food gardens. Individuals with a Mediterranean-European background for example, had a significant positive correlation with the number of residential food gardens across each territory. For an increase of one unit of the percentage of individuals with a Mediterranean-European background, the incidence rate ratio for the number of residential food gardens was increased by a factor 2.36 (Model 3d).

A similar trend was observed for citizens with a Middle-Eastern backgroud, as the incident rate ratio increased by a factor of 1.81 (Model 3d). The ethnocultural background for Mediterranean-European and Middle-Eastern individuals was thus a greater predictor of residential food gardens than homeownership (IRR of 1.13). However, further research is required as citizens with a Mediterranean-European or Middle-Eastern backgroud were not evenly distributed through each of the five territories. Although both variables were tested in the random-effects negative binomial regression model, the model was not able to calculate their variation within each territory.

Few studies have yet to integrate ethnocultural variables as predictors of residential food gardens, common motivations include the preservation of culture, tradition, and the production of fruits and vegetables not found in local food retail outlets (Darby et al. 2020). Furthermore, garden characteristics can reflect cultural backgrounds. In Chicago IL, Taylor & Lovell's (2012) study illustrated with satellite imagery that residential food gardens located in neighbourhoods with high Chinese populations, were characterized by trellises and arbours. Further statistic analysis also highlighted residential food gardens in communities with high concentration of Eastern and

Southern European and Polish origins. In Mississauga, ON (Canada), there was a high likelyhood of residential food gardens in households with European or South Aisian ethnicity.

In Malmö, Sweeden allotment gardens located in Asian communities in were characterized by small plastic-covered greenhouses and tunnels used to protect and maximize production Hochedez, (2018). The allotment gardens were not only used for personal food production but also as a means of extra income (Hochedez 2018). These previsous empirical studies have shown that gardens can be used as a place where immigrants can carry-out traditions from their homeland (Head et al. 2004). Residential food gardens located within these communities are, therefore, more than a source of food production.

Impact of education

Concerning the influence of education, in our study, individuals with a bachelor's degree or greater did not have a significant relationship with the number of residential food gardens. However, in McClintock et al., (2016), education was correlated with the presence of front yard gardens with 70% having undergraduate or graduate degrees. Knowledge has also been found to be associated with the number of wildlife gardening practices (Goddard et a., 2013), validating that gardeners with higher education levels are motivated to garden for environmental concerns (McClintock et al. 2016). Although it was not a significant variable within this study, it is correlated with the presence of residential food gardens and other forms of gardening in North America.

Impacts of age

The association between age and the number of residential food gardens was found to have a significant negative relationship with individuals between the ages of 20 and 34, 50 and 64 and 65 and over. There was no significance between the number of residential food gardens and individuals aged between 35 and 49. This result was not consistent with the literature. McClintock et al. (2016) had a high number of respondents in their 30's or below and in their 50's and above (pg.9), with the majority of participants white and retired women. Age can have a significant influence on the motivation for gardening. For example, those under the age of 50 gardened for environmental and sustainability reasons, while those over the age of 50 did not consider the environment as a motivation for gardening (McClintock et al., 2016, pg. 10). However, these motivation can sway depending on income levels or even the location of their garden. An explanation for the negative relationship between age and residential food gardens could be due to time restrictions or other engagement such as education (for those between 20 and 35) and family responsibilities (for those between 25, 50 and over). However, families with young children can also be motivated to have a residential food garden for educational purposes (Conway and Brennan 2014; Kortright and Wakefield 2011). For example, in Mississauga, ON (Canada), where the largest percentage of residential food gardens were found in neighbourhoods with school-aged children (below the age of 18) (Conway and Brennan 2014). In summary, age is not a changing predictor of residential food gardens due to the conflicts throughout the literature and the diversity of lifestyles associated with each age group.

5.6 Study limitations

This study provided a better understanding of the spatial patterns of residential food gardens across each of the five territories as well as their relationship with population denssity, socio-economic and ethnocultural variables. However, a few limitations are to be mentioned. For example, citizens growing food on balconies, in pots and in containers were not included within the study as they were not visible using satellite imagery. In addition, there are a host of variables that could be integrated within a model and tested for their correlation with the presence of residential food gardens. As this study provides one exemple, other variables such as housing type, year of construction, family size amongst others that could be integrated.

Modeling and statistical analysis remains theoretical without qualitative data to support the motivations used to better explain the pratices of residential food gardens. Furthermore, evaluating food production at the domestic level would provide greater insight on the production capacity of residential food gardens.

CHAPTER VI

CONCLUSION

Residential food gardens are an abundant form of urban agriculture throughout the MMC area and other metropolitan cities in North American (McClintock et al. 2016; Smith et al. 2005; Taylor and Lovell 2012). It is used as a multi-functional tool to alleviate a host of socio-economic challenges of the 21st century and goes well beyond its capacity to produce food in proximity to urban population and contributes to the overall health and wellbeing, livability and ecological resilience of cities (Darby et al. 2020; Duchemin et al. 2009; Grewal and Grewal 2012; Jehlička et al. 2019). Although our study has confirmed its strong correlation to homeownership, it was also significantly correlated to citizens with an annual income of $20,000 or less after-tax as well as those with a Mediterranean-European or Middle-Eastern background.

These results further confirm the plasticity of urban agriculture activities and how they are customized to the needs of communities and individuals. As urban agriculture such as residential food gardens play an important role in the development and wellbeing of communities, residential food gardens were not evenly distributed throughout each territory. Uneven distribution was mirrored in other recent studies such as in Portland, OR (McClintock et al., 2016), Chicago, IL (Taylor and Lovell 2012), or Ann Arbor, MI, (Hunter and Brown 2012).

Our study demonstrates that the distribution of residential food gardens is influenced by the complex inter-relationships of socio-economic, ethnocultural, and population density factors. Moreover, their influential weight can vary by household and community. Therefore, policy and decision-makers must pay closer attention to household and community population profiles to meet the needs of individuals and communities. Increasing access to services that provide gardening tools, supplies, information and clubs could help motivate all types of gardeners to participate in urban gardening. In addition, supporting community-led initiatives such as urban seed banks, community urban agricultural projects, or those that aim to educate citizens growing and food-related topics could contribute to greater community food scholarship. These community initiatives not only benefit those using community spaces but also those gardening in private ones. Supporting these intiatives requires funding and management at the local level with decision makers. It appears important to inform them of the benefits of supporting local urban agriculture intiatives and the barriers that can inhibit residents' success: access to space, water, materials tools and so on.

Urban agriculture is not solely the growing of food, but also integrates the harvesting and transformation of food products. Thus, with increased access to services that provide a space for community members to meet, such as local food hubs, this could results in the sharing of private space or working together to harvest and process food. As discussed throughout this study, not all citizens have the time to manage and maintain a garden, but if the work was shared amongst community memebers, this could be advantageous for all gardeners. A great example of community food service is Santropol Roulant, where all citizens are welcome to participate in the production, harvest and transformation of food. Volunteers can take food home as payment for their work as well as learn new skills. A similar approach for residential food gardens could be taken. Although it may already occur naturally, providing food programs and services in community hubs (community kitchens, equipment retals) or programs that partner community memebers could increase the space, number of gardens as well as urban food production. Furthermore, urban agriculture policy and integrare ecological aspects (the integration of pollinator gardens, urban fruit forests, ecological corridors and so on) to increase urban biodiversity. By coupling urban agricultural intiatives with those pertaining to the greening and biological diversity of cities, this would enhance the multi-use of urban spaces and add to the services and diversity of activities available to local residents. An existing example in the City of Montreal is the Corridor Écologique Darlington located in Côtes-des-Neiges-Notre-Dame-de-Grace (corridorecologiquedarlington.org) or Campus MIL located on Rue Durocher and Ave. Thérèse-Lavoie-Roux. Thus, increasing the frequency of food hubs across the urban landscape could facilitate the production of residential food gardens and provide greater connections amongst residents further developing community networks and the sharing of knowledge and food.

Lastly, as ethnocultural variables had a signicant influence on the presnce of residential food gardens, preserving this knowledge and agrobiodiversity is essential for the continued preservation of garden knowledge and urban food diversity. Integrating seed-saving programs within each territory could help preserve this diversity. Seed libraries could be integrated within existing territory services such as YMCA programs, food hubs, food banks or other community and food related services.

As the province of Québec prepares to further integrate food planing within the policy and development of cities (Food Secure Canada 2017), municipalities, must document the type and form of food assets within their communitie. As studies such as this one have deomonstrated that the presence of the residential food gardens can vary amongst territories and their population profiles, understanding their motivation for gardening is essential to customize programs to the needs and demands of communities. Using a statistical and spatial analysis has given further insight of the patterns and socio-spatial progresses influencing the presence of residential food gardens. However, further empirical data on the quantity of fruits and vegetables produced, diversity and practices need to be evaluated.

Although not all citizens want to participate in urban agriculture, due to time, interest or other reasons. As this study among others (Jehlička et al. 2019; McClintock et al. 2016; Smith et al. 2005; Taylor and Lovell 2012) have demonstrated the presence and significance of urban agriculture at the domestic level it is also important to understand how residential food gardens amongst other forms urban agriculture are supported by local food system components. For example, do community food hubs increase the number of urban agricultural activities ? If so, what are the most popular services ? Do these services reflect population profiles ? These are only some of the questions needing to be clarified.

To further integrate urban agricultural activities across regions and municipalities, funding dedicated to research and development must be invested to coordinate and evaluate the gaps and opportunities of communities. Following this research, urban agriculture, amongst other food system components would then need to be strategically integrated within the planning and development of communities. Without an official strategic plan outling the opportunities throughout communities, current municipal plans and strategies remain vague and without direction (refer to RDP-PAT urban agriculture plan or the City of Longeueil).

Therefore, further research concerning the food production capacity, types of gardening practices as well as motivations of urban gardeners is needed to evaluate its potential economic benefits. Furthermore, interviews and questions evaluating the production, sharing and services that could ecourage and compliment urban gardening (composting, food transformation, local food sharing or selling) are essential in developing more sustainable and just local food systems.

APPENDIX A

A.1 Description of the variables used within the spatial modeling

Variables acronyms	**Variable description**
Urban form	
POP_DEN_1000	Population density (divided by 1000)
Social Strat.	
PCTINAF_Less20	% Citizens earning < $20,000 per year after-tax
PCTINAF_80_More	% Citizens earning > $80,000 per year after-tax
PCTEDU_UN_AB	% Citizens with a university degree or above
PCTTOT_OWN_10	% Homeowners (divided by 10)
PCT_CAN_10	% Citizens with Canadian citizenship
PCTAGE_20_34	% Citizens between the ages of 20 and 34
PCTAGE_35_49	% Citizens between the ages of 35 and 49
PCTAGE_50_64	% Citizens between the ages of 50 and 64
PCTAGE_65_OV	% Citizens between the ages of 65 and over
Ethnocultural	
South_Asia	% Citizens from South Asia
East_Asia	% Citizens from East Asia
Middle_East	% Citizens from the Middle East
North_Africa	% Citizens from North Africa
Western_Europe	% Citizens from Western Europe
Mediterranean_Europe	% Citizens from Mediterranean Europe
South_Western_Europe	% Citizens from South Western Europe
Central_Europe	% Citizens from Central Europe
Latin_America	% Citizens from Latin America
Caribbean	% Citizens from the Caribbean

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