8-13-2021 1:00 PM

Residential Greenness and Substance Use

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Epidemiology and Biostatistics

Abstract

INTRODUCTION: Research has identified positive associations between green space and health and green space and mental health. Substance use outcomes, however, have received considerably less attention.

OBJECTIVE: The purpose of this study was to investigate associations between residential greenness and patterns of substance use among transitional aged youth (age 15-25) in Canada.

METHODS: This study utilized three waves (2016-2018) of the Canadian Community Health Survey (CCHS) as well as residential greenness data from the Canadian Urban Environmental Health Consortium (CANUE). Multivariable regression was used to explore variation in the pattern of substance use between greenness quartiles. The sample included 14,070 transitional aged youth.

RESULTS: Higher levels of residential greenness were associated with lower odds of frequent binge drinking, lower odds of tobacco use, and greater odds for marijuana use.

CONCLUSION: Living in greener neighborhoods may confer benefits to substance use tendencies among transitional aged youth.

KEY WORDS: Green space, greenspace, substance use, mental health

Summary for Lay Audience

Research has found that living near green spaces, like residential parks, conservation areas, public gardens, etc., can have positive impacts on an individual's health. People who live in greener areas tend to have better physical health and better mental health than those who do not. Green spaces are believed to positively impact health in a variety of ways, including: the promotion of physical activity, the reduction of pollutants, social cohesion, and psychological restoration.

An important dimension to green space and health/mental health that has received little attention is substance use. This study is the first to investigate the association between green space and alcohol, tobacco, and marijuana use, among transitional aged youth (ages 15-25) living in Canada. Using three cycles of the Canadian Community Health Survey (CCHS) in conjunction with residential greenness data, patterns of substance use were compared between areas with high levels of greenness and areas with low levels of greenness. The results of the study suggest that living in greener areas may offer protective benefits for certain patterns of substance use. Individuals living in greener areas were found to binge drink and smoke tobacco less frequently than those living in less green areas. These findings speak to the importance of green spaces to help mitigate both substance using and abusing tendencies, and the potential for green spaces to be utilized in the delivery of addiction services.

Acknowledgements

Firstly, I would like to thank my supervisors Dr. Jamie Seabrook and Dr. Saverio Stranges for their mentorship and guidance throughout the course of this research. Your constant encouragement and expertise gave me confidence in undertaking research in such a sparsely populated area. Thank you for always being available and for setting such a high standard for academic scholarship. I would also like to thank my committee members, Dr. Jason Gilliland and Dr. Kelly Anderson, for all of the time and feedback that you contributed to this work.

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Abbreviations

SES	Socioeconomic Status
DALY	Disability Adjusted Life Years
YLD	Years Lived with Disability
YLL	Years of Life Lost
NAT	Nature Assisted Therapy
NDVI	Normalized Difference Vegetation Index
SDQ	Strengths and Difficulties Questionnaire
GHQ	General Health Questionnaire
TDS	Total Difficulties Score
CCHS	Canadian Community Health Survey
CANUE	Canadian Urban Environmental Health Research Consortium
BMI	Body Mass Index

CHAPTER 1: INTRODUCTION

1 Introduction

Green space research has expanded over the past decade (Hartig *et al*., 2014; Jarvis *et al*., 2020). Investigators across multiple disciplines have explored the diverse ways that green spaces can influence health. Research has documented positive associations between green space and self-perceived health (Dadvand *et al*., 2016; de Vries *et al*., 2003; Maas *et al*., 2006; Mitchell & Popham, 2007), green space and reduced mortality (Gascon *et al*., 2016; van den Berg *et al*., 2015; Villeneuve *et al*., 2012), and green space and mental health (Tillmann et al, 2018; Astell-Burt *et al*., 2014; Beyer *et al*., 2014; Bratman *et al*., 2019; Nutsford *et al*., 2013). The latter area of research has investigated a variety of general (e.g., wellbeing, overall mental health) and specific outcomes (e.g., depression, anxiety, stress, ADHD) but has yet to explore the impact of green space on substance use and addiction (Wiley *et al.*, 2020).

The following chapter will describe what green spaces are, how they are linked to health outcomes, and why they should be considered in the context of substance use. Current patterns in substance use will be described on a global and national level and an argument will be advanced as to why these outcomes should be considered in the context of green space research.

1.1 The Green Space Conundrum

Green space is used to mean a variety of things. For example, some authors define green space in relation to a range of natural environments like forests or parks (Stigsdotter *et al*., 2010), others use it to describe land-use areas void of buildings, roads, or gardens (Astell-Burt *et al*., 2013; Groenewegen *et al*, 2006; Mitchell & Popham, 2007), while some use it in the context of natural vegetation cover in urban environments (Cohen-Cline *et al*., 2015; Wilker *et al*., 2014).

Conceptually then, green space can be thought of in a multidimensional way that can include elements of both the built and natural environment. Defining exactly which elements qualify as green space, however, remains a problem. To help make sense of this theoretical conundrum, Taylor & Hochuli (2017) analyzed how authors used the term and provided a more coherent definition. Their analysis revealed that green space is defined in at least six different ways. These range from thematic based definitions, i.e., definitions that converge around a single organizational element (e.g., ecosystems, vegetation, land use) to example-based definitions that articulate exactly what is eligible for consideration (e.g., combined areas of neighbourhood parks, forests, and gardens). Collectively, Taylor & Hochuli (2017) argue that these definitions converge around two central pillars. The first defines green space in relation "to bodies of water or areas of vegetation in a landscape, such as forests and wilderness areas, street trees and parks, gardens and backyards, geological formations, farmland, coastal areas and food crops" (p. 29), while the second refers to green space in terms of "urban vegetation, including parks, gardens, yards, urban forests and urban farms − usually relating to a vegetated variant of open space" (p. 29). While such a definition remains seemingly broad, it nonetheless captures the diversity of elements used in the literature. Such a definition also highlights the need for future researchers to be explicit about what constitutes green space.

1.2 Green Space and Health

1.2.1 Causal Mechanisms

Just as green spaces vary considerably, so too do the ways in which they influence our health. Numerous biological, psychological, and social mechanisms linking green space to health have been proposed and supported by evidence (Hartig *et al*., 2014; Kuo, 2015; Markevych *et al*.,

2017). An early review identified twenty-one empirically supported pathways which included: environmental mechanisms (e.g., reduced pollution, reduced heat, negative air ions), psychological mechanisms (e.g., relaxation, attention restoration) and behavioural mechanisms (e.g., physical activity, social ties, sleep). Fewer mechanisms, however, have been explored extensively (Hartig *et al*., 2014). In their review of mechanisms linking green space to health, Hartig *et al*. (2014) described evidence around pathways that have received considerable research attention. These pathways include air quality, physical activity, social cohesion, and stress reduction. While the quality of evidence varied, support was noted for each mechanism. Air quality, for example, was linked to health in a contradistinctive way. Trees and natural vegetation allowed for the buffering of pollutants and particulate matter, but they also contributed to pollution in the form of hydrocarbons. Similarly, the release of pollen from certain trees and plants could exacerbate allergies, also leading to negative health outcomes. Physical activity, social cohesion, and stress reduction, on the other hand, all displayed unilateral paths to better health. The strongest evidence was found for pathways involving restorative effects, like stress reduction, followed by social cohesion and physical activity (Hartig *et al*., 2014).

More recently, Markevych *et al*. (2017) put forth a theoretical framework for describing pathways, with updated evidence for both beneficial and adverse mechanisms. Expanding off the work of Hartig *et al*. (2014) they describe beneficial pathways with reference to three domains: harm reduction pathways (reduced air pollution, reduced exposure to heat, reduced exposure to noise), restoration capacities (stress reduction, attention restoration), and capacity building pathways (encouraging physical activity, facilitating social cohesion). Furthermore, in addition to the one adverse pathway noted by Hartig *et al*. (2014), i.e., pollen concentration and spread, Markevych *et al*. (2017) note at least three others: 1. green spaces as disease vectors (primarily

for zoonotic disease). 2. green spaces as crime generators. 3. green spaces as population displacers (e.g., urban greening driving out low socioeconomic status (SES) individuals due to increased rent and property taxes).

1.2.2 Methodological difficulties

Another important dimension to causal pathways in green space research is their ability to intersect, or as *Hartig et al*. (2014) describe, intertwine. Markevych *et al*. (2017) describe multiple ways through which this could occur. Exercising in a green space, for example, could evoke the action of several pathways. The mere act of exercise could underscore health benefits, but so too might the processes of psychological restoration and social cohesion. Depending on the combination of mechanisms then, the resulting effects could either be synergistic or antagonistic for any given outcome.

In addition to the theoretical obscurity surrounding causal mechanisms are more fundamental methodological challenges. At the core of these challenges are issues related to the measurement of green space and the substantiation of meaningful contact (Hartig *et al*., 2014; Jarvis *et al*., 2020; Markevych *et al*., 2017). Hartig *et al*. (2014) sum up the issue best by explaining "[Simply because] people live near natural spaces, report visiting them, or position themselves spatially within them does not mean that individuals actually have had contact with nature in a way that affects their health" (Hartig *et al*., 2014, p. 219). This speaks to two important points. First, confounding represents a very real threat to green space research. Second, even when confounding is assessed, certain green space measures may still lack the granularity to bridge the gap between exposure and meaningful contact.

Outcome measurement also obscures a clear understanding between green space and health associations. Health-related outcomes involve biological, psychological, and social dimensions, some of which target positive elements of health and others negative elements. Furthermore, measurement instruments, even for a specific outcome, can vary considerably, further adding to a variegated body of research (Hartig *et al*., 2014).

1.3 Substance Use Patterns

1.3.1 Substance Use Globally

Alcohol, tobacco, and marijuana use is a global phenomenon. Alcohol and tobacco remain the most commonly used substances, followed by marijuana (Degenhardt *et al*., 2012; Degenhardt *et al*., 2013; NIDA, 2020). It is estimated that nearly half of the world's population actively uses alcohol (Anderson, 2006), 15% smoke tobacco, and nearly 4% use marijuana (Peacock *et al*., 2018). While prevalence of substance use varies considerably between countries, some overall trends are apparent. The *per capita* use of alcohol varies widely from country to country. European countries have some of the highest *per capita* rates, followed by the Americas and South East Asia (Anderson, 2006). Similarly, heavy episodic drinking and tobacco use is more concentrated in European countries, while marijuana, opioid, and cocaine use is more concentrated in high-income North American countries (Peacock *et al*., 2018). Furthermore, although the prevalence of substance use has stabilized across many regions, economic development may continue to fuel higher alcohol and illicit drug use in low-income countries (Anderson, 2006).

In addition to the prolific nature of global substance use is the accompanying societal cost. Substance use is a leading contributor to disability adjusted life years (DALY), years lived

with disability (YLD), and years of life lost (YLL) (Degenhardt *et al*., 2013; Degenhardt & Hall, 2012; Griswold *et al*., 2018; Whiteford *et al*., 2013). In their analysis of the 2010 global burden of disease study, Whiteford *et al*. found that mental and substance use disorders accounted for 183.9 million DALYs, representing 7.4% of the total burden of disease. Furthermore, they found that these disorders were the leading contributor to global YLD and that alcohol and drug use disorders contributed to approximately 85% of YLL for all mental and substance use disorders. Not surprisingly, age played an important role for the overall distribution of drug and alcohol DALYs. The greatest proportion of DALYs for drug use disorders were concentrated in those aged 15-29 years, while alcohol-related DALY were concentrated in the 25-50 year age group (Degenhardt *et al*., 2013; Whiteford *et al*., 2013), thus leading to premature adverse outcomes and long-term disability.

In tandem with the physical costs of substance use is the mounting financial burden. Alcohol and drug use disorders contribute to indirect costs, like lost productivity, as well as direct costs incurred by the health care system. Rehm *et al*. (2009) estimated that more than 1% of any given country's GDP is spent on alcohol use disorders, with costs per head reaching as high as $837 in high-income countries and $524 in middle-income countries. Like alcohol, tobacco-related disease contributes to massive global costs. Goodchild *et al*. (2018) estimated that approximately 1.8% of the world's GDP ($1852 billion) is spent on tobacco-related illness and low- and middle-income countries bear nearly 40% of these total economic costs.

1.3.2 Substance Use in Canada

Substance use in Canada follows global trends. Alcohol, tobacco, and marijuana remain the three most used substances (Adrian & Smart, 2001; Government of Canada, 2019; Rotermann *et al*.,

2015). Alcohol is by far the most used substance in Canada, with 78% of Canadians reporting past year use (Government of Canada, 2019). The prevalence of alcohol use is similar for men and women and has remained constant with 2015 estimates. While patterns of alcohol use vary considerably, most Canadians report drinking habits that fall within national guidelines. Canada's low-risk drinking guidelines state that women should drink no more than 10 drinks per week, with no more than two drinks per day most days, and men should drink no more than 15 drinks a week, with no more than three drinks per day most days. Furthermore, the guidelines state that on any given occasion, women should drink no more than three drinks and men no more than four (Canadian Center on Substance Abuse, 2013). In 2017, however, 21% of Canadians exceeded the frequency guideline and 15% exceeded the quantity guideline (Government of Canada, 2019).

Cigarette smoking mirrors global levels, with approximately 15% of Canadians partaking in daily use. The prevalence of cigarette smoking has held constant for youth (15-19-year-old's) and young adults (20-24-year-old's) at 8% and 16%, respectively, while it has increased for adults (25+) from 13% in 2015 to 16% in 2017. Finally, prevalence for past year marijuana use was 15% in 2017, up 3% from 2015 levels (Government of Canada, 2019).

Substance use varies considerably by province. Past year alcohol use is highest in Quebec; smoking prevalence is highest in the eastern provinces of Newfoundland and New Brunswick; and past year cannabis use is highest in British Columbia (Government of Canada, 2019). Problematic substance use (i.e., risky substance use below clinical thresholds) also varies considerably by province. Veldhuizen *et al*. (2007) found that patterns of problematic substance use were more concentrated in western and eastern provinces than in Ontario or Quebec. Moreover, they found strong associations between province of residence and problematic

substance use, even after controlling for individual risk-factors. Indeed, the odds of problematic substance use were 36% times greater in British Columbia than in Ontario.

Like the global context, substance use in Canada is a leading contributor to DALYs and YLDs. In 2016, mental and substance use disorders were the second leading cause of YLDs and the fourth leading cause of DALYs in Canada (Lang *et al*., 2018). Trends from 1990 to 2016 reveal that DALYs attributable to substance use is increasing. Exposure to tobacco, for example, continues to be the leading risk factor for all-cause DALYs, while alcohol and drug use attributable DALYs have increased by approximately 13% and 8.5% respectively, for the same period (Alam *et al*., 2019).

The economic costs related to substance use in Canada are also far reaching (CCSA, 2020; Rehm *et al*., 2007; Single *et al*., 1998). The most recent data suggests that substance use costs Canadians $46.0 billion annually. Comprised of healthcare costs, loss of productivity costs, enforcement costs, and other direct costs, substance use affects the economy broadly. Most costs are related to loss of productivity and healthcare, each contributing to deficits of $20.0 billion and $13.3 billion, respectively. Furthermore, it is legal substances, primarily alcohol and tobacco that derive most of the costs (CCSA, 2020).

1.4 Thesis Rationale

Given the extent of positive associations between green space and health, and more specifically green space and mental health, it is surprising that substance use outcomes have not been explored. Coupled with the scale of substance use globally and nationally, and the associated economic and health-related costs, research in this area could represent a promising new frontier. Within Canada, research in this area is particularly timely. Cunningham & Koski-Jännes (2019),

for example, note that government policies related to the control of alcohol and marijuana have been greatly relaxed. Alcohol is now sold in both government and retail locations with longer hours of operation, while marijuana has become legalized. Additionally, perceptions regarding the dangers of substance use have remained relatively unchanged (Cunningham & Koski-Jännes, 2019; Dakkak et al. 2018). Collectively then, changes to the control of substances, coupled with the high prevalence of substance use behaviour, positions the Canadian context as a viable area for green space research.

1.5 Research Objectives

This thesis contributes to the broader green space and health literature by exploring potential associations between residential greenness and patterns of substance use. Given the lack of evidence regarding green space and substance use, this thesis will explore potential associations amongst a cohort of Canadian transitional aged youth (15-25 years old). Outcomes will include the three most used substances−alcohol, tobacco, marijuana−and will focus on *patterns of use*, as characterized by volume and frequency measures. Recognizing the void of research in this area, this thesis takes a broad exploratory approach to the potential association between green space and substance use. The primary goal, therefore, is to evaluate the independent association between greenness and substance use. At the outset, it is hypothesised that higher levels of residential greenness will be associated with lower levels of substance use. The following two research questions will be explored:

1. What is the prevalence of alcohol, tobacco, and marijuana use among individuals aged 15-25 years-old?
2. Is residential greenness associated with (a) frequency and (b) intensity of alcohol, tobacco, and marijuana use?

CHAPTER 2: LITERATURE REVIEW

2 Introduction

Very little research has explored the association between green space and substance use. In a recent editorial, Wiley *et al*. (2020) advocated for future research in this area, noting only peripheral evidence on the matter. Framing their discussion around the wider literature of green space and mental health, the authors concluded that while outcomes related to substance use have yet to been considered, such explorations represent a promising new frontier for green space and mental health research. From their discussion, and in conjunction with a deeper exploration of the wider literature, there are at least four categories of research to draw upon: (1) nature-assisted therapy and substance use, (2) residential parks and substance use, (3) residential greenness and substance use, and (4) green space and mental health. Evidence from the first three categories remains quite limited, while evidence from the fourth category is expanse and will form the bulk of this chapter.

2.1 Peripheral Literature

2.1.1 Nature-Assisted Therapy and Substance Use

In their systematic review of nature-assisted therapy (NAT) in experimental and observational studies, Annerstedt and Währborg (2011) note the empirical tradition of utilizing nature-based interventions for the treatment, management, and promotion of health. Broadly defined as an "intervention with the aim to treat, hasten recovery, and/or rehabilitate patients with a disease or a condition of ill health, with the fundamental principle that the therapy involves plants, natural materials, and/or outdoor environment" (p.372), they describe two classes of NAT: social and therapeutic horticulture, and natural environments therapy. The former class of intervention

involves the cultivation and care of plants and gardens as a key element to a patient's treatment, while the latter category involves group-based experiential learning using wilderness and adventure therapies.

In terms of substance use outcomes, several studies have investigated the use of NATs for individuals with both substance abuse problems and substance dependence. Studies within natural environment therapy, for example, have investigated the effects of wilderness or adventure therapy for teens/adolescents (Bettmann *et al*., 2017; Kennedy, 1993; Russell, 2005) and adults (Bennett *et al*., 1998) struggling with substance abuse or use disorders. Most of these therapies involved multi-week interventions that included camping, hiking, and backpacking based activities. Each study noted positive associations between NAT and substance use outcomes with effects ranging from reduced use (Bettmann *et al*., 2017; Russell, 2005) to abstinence at one year follow-up (Kennedy, 1993). Studies that utilized social and therapeutic horticulture were sparser. One study investigated the use of horticulture therapy on the future vulnerability and resilience to addiction among incarcerated individuals (Richards & Kafami, 1999). Eligible participants had a documented history of substance abuse and partook in a six-month program that involved weekly gardening projects. While limited support was found for resilience to addiction, support was found for vulnerability to addiction (Richards & Kafami, 1999).

Collectively, research involving NAT has demonstrated positive associations between green space and substance use, but these results must be contextualized within a particular population, subject to a particular intervention. Green space, in this example, is defined by engagement with nature under the direction of a clinical intervention. All the subjects had

documented histories of substance use/abuse problems, so the results cannot be generalized to a broader 'at-risk' population.

2.1.2 Residential Parks and Substance Use

Research from environmental criminology provides a different context for thinking about green space and substance use. Instead of focusing on characteristics of the individual, this research highlights the role of parks themselves to either inhibit or promote crime (Groff & McCord, 2012). Research in this area considers both the contested nature of public parks (Groff & McCord, 2012) as well as the area immediately surrounding parks (Boessen & Hipp, 2018; Kimpton *et al*., 2017) to describe patterns of crime. When considering the distribution of violent crime, property crime, and disorder crime, which includes drug and alcohol offences, Groff & McCord (2012) found that all three categories of crime were more concentrated within the parks and surrounding areas, compared to a random sample of 500 intersections within the city. Moreover, disorder crimes were the most concentrated and represented a twofold increase compared to other areas of the city (Groff & McCord, 2012). Kimpton *et al*. (2017) took a similar approach to describing patterns of crime, but they focused more on the composition of parks (i.e., amenities), as well as the socioeconomic makeup of the surrounding neighbourhoods. They found that parks with more amenities attracted more crime, with a 331% increase in drug crime comparing amenity-rich to amenity-poor parks. This research provides evidence that neighbourhood parks are implicated in substance use processes (i.e., distribution, procurement, and use) but adds little to our understanding of substance use patterns for the broader public. A recent study, however, provides a more concrete link between neighbourhood parks and substance use. Kotlaja *et al*. (2018) explored the association between the presence of

neighbourhood parks and substance use in a cohort of adolescents in Chicago. When controlling for a host of individual- and neighbourhood-level characteristics, they found that having a higher proportion of parks and playgrounds in ones' neighbourhood was associated with greater odds of engaging in substance use behaviours (Kotlaja *et al*., 2018). This study, however, did not take into consideration park amenities, nor did it consider greenness in any way. Collectively then, environmental criminology research alludes to potential associations between green space and substance use, though it has not explicitly considered both concepts simultaneously.

2.1.3 Green Space and Substance Related Mental Health

The literature on green space and mental health is extensive, and includes studies that investigate the role of green space in a variety of mental health outcomes (Bratman *et al*., 2019). Research ranges from studies that explore associations with specific mental health outcomes for specific populations (Amoly *et al*., 2014; Nichani *et al*., 2017) to research that focuses on broad concepts of mental health for entire populations (Houlden *et al*., 2017; Pope *et al*., 2018; Song *et al*., 2018).

Only one study was identified that explicitly investigated the role of green space on a series of substance use outcomes. Engemann *et al*. (2019) conducted a large population-based study that investigated the role of residential green space during childhood on the likelihood of developing a psychiatric disorder later in life. Green space was measured using mean-annualized Normalized Difference Vegetation Index (NDVI) scores and were recorded for each participant from birth until age ten, and mental health outcomes were collected from national registries. Seventeen psychiatric outcomes were investigated and included alcohol abuse, cannabis abuse, and substance abuse. In total, and except for two disorders, they found that the risk of developing

any psychiatric disorder was significantly higher for individuals with the lowest, compared to the highest, levels of green space. While the risk of developing any disorder ranged widely, from 15% to 55%, with substance abuse, cannabis abuse, and alcohol abuse, showing the strongest associations, respectively (Engemann *et al*., 2019). This provides stronger evidence regarding the association between green space and substance use, though it again remains limited in terms of broad generalizability. Since this study assessed substance related disorders, only a small category of substance use behaviour, i.e., high risk/problem use behaviour, was captured.

2.1.4 Residential Greenness and Substance Use

In addition to the peripheral evidence noted thus far, two recent studies took a more direct approach in exploring the relationship between green space and substance use (Martin *et al*., 2020; Mennis *et al*., 2021). The first study explored the association between residential greenness and smoking prevalence, while the second assessed the potential for green spaces to moderate substance use outcomes.

In their study on the relationship between residential greenness and smoking, Martin *et al*. (2020) found that individuals living in the greenest areas was associated with a 20% reduction in smoking prevalence, even after controlling for suspected confounders. To more fully evaluate this association, they also explored variation between current and former smokers based on levels of residential greenness. They found that the greenest areas also had a higher proportion of former smokers compared to the least green areas. Collectively then, the authors hypothesised that the protective association might be defined more by an increase in smoking cessation then by a decrease in smoking initiation.

A second, broader, study investigated the potential for green spaces to moderate substance use outcomes. More specifically, Mennis *et al*. (2021) examined the moderating effect of greenness on the relationship between peer networks and substance use, as well as interactive effects with sex and executive function deficits. They found that residential greenness reduces the likelihood of substance use amongst prosocial groups in the greenest areas and that the interactive effects were stronger for individuals with greater executive functioning deficits, suggesting that those more disadvantaged stand to gain the most. Unfortunately, however, substance use was only measured in relation to risky/abusive use, limiting its generalizability to other 'high-risk' populations.

2.2 Green Space and Mental Health

Given the lack of studies that have explicitly explored the relationship between green space and substance use, the remainder of this chapter will focus on the broader relationship of green space exposure and mental health. Reviewing the literature in this way is beneficial for several reasons. Substance use patterns, and in particular risky substance use, is naturally nested within the broader framework of mental health. A thorough investigation of mental health, then, will further elucidate gaps within this literature. Secondly, a review of this nature will help identify strengths and shortcomings of particular methodologies. Indeed, the green space literature is rife with different methodologies, especially as they relate to exposure measurement, and an expansive review can help contextualize best practices.

The following sections will take the form of a critical review of existing systematic reviews on this topic. The objectives for the review are as follows: 1. Explore the extent to which substance use/abuse outcomes have been explored within the green space mental health

literature, 2. Describe the overall association between green space measures and mental health outcomes in children and adults.

2.2.1 The Exposure Problem

For this critical review, a clarification needs to be made regarding the use of the word exposure. From an epidemiological perspective, exposure represents "the variable whose causal effect is to be estimated" (Porto, 104). Exposure, in this sense, can represent a variety of states, each of which can influence a subject in terms of both a presence and magnitude of effect. A study, for example, interested in the effects of radiation on cancer incidence could thus classify exposure based on a simple yes/no designation (i.e., presence of exposure) and/or, it could classify exposure on a continuous or ordinal scale (i.e., magnitude of exposure). The important unifying characteristic, however, is that exposure is taken to represent a single variable with a hypothesized causal connection to the outcome. In green space research however, exposure is operationalized in many ways and often without reference to a particular causal mechanism. Studies will sometimes describe an association between green space exposure and a given outcome but fail to articulate exactly how the exposure was measured (Taylor & Hochuli, 2017). The problem with using exposure in this general sense is that the nuance of the actual measure is lost. Using the same word, i.e., exposure, to describe several distinct states thus glosses over the unique contributions of each state. As a simple example, consider two distinct types of green space exposure, residential greenness and visits to green space. Depending on the outcome of interest, both can be important; however, they both imply very different things. If the hypothesized causal mechanism involves engagement with a physical space, then the term exposure logically aligns closer with visits than it does with residential greenness. Overall,

exposure tends to be used loosely in green space research and, any time it is used, it should be done so with explicit reference to a specific measurement and a hypothesized causal mechanism.

These problems are further compounded in systematic reviews where multiple types of exposure are reported on. To help clarify the use of the word exposure, this review will use it in the broadest sense to denote the entire category of measurements.

2.3 Review of Reviews

2.3.1 Search Strategy

Two bibliographic databases, PubMED and SCOPUS, were searched for systematic reviews that assessed the relationship between green space or natural environments with mental health. Search terms related to green space included: “green space” or “greenspace” or “natur*” and search terms for mental health included: “mental health” or “mental wellbeing” or “mental well-being”. Eligibility included: (a) systematic reviews that reported on child and/or adult populations; (b) Systematic reviews that reported on some form of green space or nature exposure; (c) systematic reviews that reported on multiple mental health outcomes (either related to mental health in general or specific disorders/components of mental health).

A total of five systematic reviews were identified and included for further review. All five Systematic Reviews (SR) were critically appraised using The Center for Evidence Based Medicine’s critical appraisal guidelines (see appendix for full appraisals). One SR was identified as having high bias and was omitted from the narrative synthesis of results. The studies included in the omitted SR, however, were all captured in the other reviews.

2.3.2 Systematic Review Characteristics

Three of the SRs were conducted in 2018 and one in 2015. The number of included studies ranged considerably from 21 to 52. Two of the SRs focused exclusively on children (Tillmann *et al*., 2018; Vanaken & Danckaerts, 2018), one focused exclusively on adults (Houlden *et al*., 2018), and the other reported on both children and adults (Gascon *et al*., 2015). Three SRs formally assessed the quality of the included studies though only two reported their findings with explicit mention to that assessment (Tillmann *et al*., 2018; Houlden *et al*., 2018). Within each SR, the dominant study design for included papers was cross-sectional, followed by longitudinal studies, then ecological/controlled and uncontrolled case studies. All SRs included studies from multiple countries. European studies were strongly represented in all the SRs, with the United Kingdom in particular, followed by North American studies.

2.3.3. Results

2.3.3.1 Green Space and Mental Health for Children

In total, three systematic reviews investigated associations between green space and mental health for children. This section, however, will focus only on two given overlap and the very small number of included studies in the Gascon *et al*. (2015) review.

The remaining two reviews, Tillmann *et al*. (2018), and Vanaken & Danckaerts (2018), explored the relationship between green space/nature and mental health in children and adolescents. The former reported on studies that included children from birth to age eighteen, while the latter included children and adolescents from birth to age twenty-five. Both discussed the role of different ‘exposure’ types, but Tillmann *et al*. (2018) was the only review that explicitly stratified their results by each ‘exposure’ category.

Tillmann *et al*. (2018) classified green space 'exposure' into three categories: accessibility, exposure, and engagement. Each category represented an increasing level of interaction with nature over its former category. Accessibility, for example, represented the lowest level of interaction by implying only a likelihood of contact. Exposure, a level up, was the broadest category and included being subject to views, contact, or some direct influence of nature. Finally, engagement represented the highest level of interaction with nature and implied direct and sustained contact. In total, good quality evidence was noted for associations between nature exposure and nature accessibility with mental health outcomes. The former category had the largest ratio of significant to non-significant findings followed by accessibility. Engagement, on the other hand, had more non-significant than significant findings. In terms of mental health outcomes, the authors reported on both general and specific outcomes. Overall positive associations (i.e., more significant than non-significant findings) between nature and mental health were found for ADD/ADHD, stress and resilience, but not for self-esteem or depression. For general mental health outcomes, overall positive associations were noted for overall mental health and health-related quality of life but not for emotional wellbeing.

Vanaken and Danckaerts (2018) also discussed the role of different green space 'exposures' on mental health, however, they did so in a less formalized approach and would occasionally use the term loosely without reference to an explicit type of measurement (i.e. satellite imagery, distance to nearest park, etc.). This made the interpretation of results for some outcomes (e.g. emotional and behavioral difficulties) less clear. In total, Vanaken & Danckaerts (2018), reported on three categories of mental health outcomes: emotional and behavioral difficulties, emotional wellbeing, and neurocognitive development. Of all the included studies the most common outcome reported on was emotional and behavioral difficulties. The vast

majority of these studies used the Strength and Difficulties Questionnaire, or a subset of the SDQ, and noted several positive associations with green space 'exposure'. The domain of hyperactivity and inattention showed the strongest results (5/6 findings), followed by the peer problem domain (4/5 findings). Mixed results were found for the other three domains: conduct, emotional symptoms, and prosocial behaviour. Studies that used a subset of the SDQ relied on the Total Difficulties Score, a measure of general mental health, and found an overall positive association between green space exposure and Total Difficulties Score (TDS). While 7/9 studies noted this association, Vanaken and Danckaerts (2018) did not fully discuss the role of exposure measurement in these findings. They noted that accessibility measures had stronger associations than average greenness measures, but they did not articulate this distinction any further. Closer investigation of the cited studies revealed that exposure measurement varied extensively between the studies and included questionnaires, NDVI, and land cover measurements.

Three other studies reported on emotional and behavioural difficulties using instruments other than the SDQ. One study found a decrease in aggressive behaviour with exposure to green space, the second found a reduction in depression with increasing neighbourhood greenness, while the third found no association between green space exposure and General Health Questionnaire (GHQ) scores.

Mental wellbeing outcomes were reported in four studies. Exposure measurement varied between studies and included quantity and size of green space, time spent in green spaces, average greenness, and access to green spaces. Two of the studies noted beneficial associations while two found no associations.

Neurocognitive outcomes were explored in four studies. Most studies in this category relied on residential greenness measures and found some evidence of a beneficial association.

One study found an inverse relationship between naturally covered land and deficits in visio-motor and language development. A second study found improvements in working memory and attentiveness with increasing levels of surrounding greenness at the residential and school level.

2.3.3.2 Green Space and Mental Health for Adults

Two systematic reviews investigated associations between green space and mental health for adults. Both complemented each other well, with one focusing on negative mental health and the other on positive mental health. Both found evidence of positive associations between green space and mental health, but the results varied by green space 'exposure' (Gascon *et al*., 2015; Houlden *et al*., 2018).

Gascon *et al*. (2015) categorized 'exposure' into three categories: surrounding greenness, access to green space, and quality of green space. All categories contained some beneficial evidence but 'surrounding greenness' was the only category where the overall evidence, from several good quality studies, pointed to a positive association. Studies that utilized 'surrounding greenness' as an exposure reported on a host of general (stress, mental distress, perceived mental health, wellbeing) and specific (depression, anxiety) mental health outcomes. Most of these studies (13/18) found a lower risk of poor mental health or a mental health related disorder with increasing greenness. In terms of 'access to green space', the results were mixed. Six studies reported on this exposure, with three studies finding negative associations between distance to the nearest green space and mental health in general, depression, and treatment for mood and anxiety disorders. The remaining three studies found either no association (n = 2) or an association (n = 1) for only a subgroup of the population (e.g., black teens). Lastly, 'green space quality' was reported on in two studies, with a benefit only noted for physically active women.

Like Gascon *et al*. (2015), Houlden *et al*. (2018) evaluated the association between green space and mental health by stratifying ‘exposure’ into various categories. Six categories were used that expanded off Gascon’s work and provided more finite distinctions. These included: ‘amount of local green space’, ‘green space type’, ‘green space visits’, ‘green space views’, ‘green space accessibility’, and ‘subjective connection with nature’. Additionally, instead of focusing on aspects of negative mental health, they focused on positive mental health through concepts of hedonic and eudaimonic wellbeing. The former, according to the authors, represents a construct that encapsulates happiness and life satisfaction, while the latter represents personal fulfillment and purpose in life. Unfortunately, however, they did not articulate how these concepts were operationalized and ultimately dichotomized the outcomes for their review.

Overall, the authors found evidence for an association between green space and mental wellbeing, with more evidence favoring hedonic wellbeing than eudaimonic wellbeing. ‘Amount of local green space’ showed the strongest evidence of an association amongst all the ‘exposures’ and was rated as adequate. All the studies (n = 4) that investigated life satisfaction, for example, found significant associations with increasing levels of greenness in urban areas. Similarly, consistent evidence was found for an association between increasing greenness and lower GHQ scores (7/8 studies). The authors noted that point-estimates varied considerably for both outcomes, with small estimates amongst the life-satisfaction outcomes and considerable variation amongst the GHQ outcomes.

Limited overall evidence was found for associations involving ‘green space visits’ and ‘green space accessibility’. Measurement of green space was diverse for both categories and included wilderness adventure, walking in ‘natural’ and green environments, self-reported visits, and distance to the nearest public park. Results involving ‘green space visits’ were mixed, with

consistent and positive evidence noted only for quality of life and general mental health (as measured by GHQ) outcomes. Several studies that investigated ‘green space accessibility’ found positive associations but measurement of the exposure varied greatly. Some studies relied on qualitative assessment, while others used objective measures of varying distances (e.g., 100m, 300m, 500m, >1km).

Inadequate overall evidence was found for the remaining three exposures - ‘green space type’, ‘green space views’, and ‘subjective connection with nature’. Studies that were classified into the ‘green space type’ used a variety of subjective and objective measures to distinguish green spaces. Subjective measures included classification of green spaces as serene, wild, lush, spacious, or cultural, while objective measures distinguished green spaces by their vegetation density using land surveys and satellite images. The authors noted that interpretation of studies within this category were heavily impeded by the diversity of both exposure and outcome definitions. ‘Green space views’ were reported in 3 studies with mixed results and small sample sizes. ‘Subjective connection with nature’ was reported in 7 studies, all of which utilized *The Connectedness to Nature Scale* to assign exposure levels. While most of these studies found positive associations with mental wellbeing, with consistent and moderate effect sizes, 5 of the studies were of poor methodological quality.

2.3.4 Discussion

For children and adolescent populations, both systematic reviews converged on several findings. Both reported overall evidence for the beneficial association of green space on emotional and behavioural difficulties. ADD/ADHD, and hyperactivity and inattention measures showed consistent negative associations with various green space exposures. Stress, resilience, and

conduct problems also showed consistency in their association with green space, though these outcomes were not independently explored in both systematic reviews. Evidence regarding other emotional and behavioural difficulties, like aggression and depression, remains mixed. Vanaken and Danckaerts (2018) reported a beneficial effect of neighbourhood greenness on depressive symptoms from two studies but did not discuss the overall quality of the studies. Tillmann *et al*. (2018), on the other hand, were explicit in their evaluation of this outcome. A total of three quality studies reported on six findings and only two showed significant associations.

Both systematic reviews were also consistent in their findings regarding mental/emotional wellbeing. While both included a different number of studies, the distribution of significant associations was similar at approximately 50%. Of the four studies reported on by Vanaken and Danckaerts (2018), only 2 found significant associations, while Tillmann *et al*. (2018) found 10 significant associations (of 23) amongst the 15 quality papers that reported on this outcome.

Positive associations for overall mental health were also consistent between both reviews. Vanaken and Danckaerts (2018) reported on total difficulty score (TDS) as a proxy for general mental health and noted that all seven included studies documented positive associations with various green space exposures. Tillmann *et al*. (2018), on the other hand, reported on general mental health based on several measures including psychological wellbeing, psychological distress, and overall mental health. Most of the included studies relied on engagement types of ‘exposure’ (adventure and wilderness programs) and most found significant associations (8/12 findings).

Within adult populations, both systematic reviews found positive evidence that green spaces can play a meaningful role in the management of mental health. While both systematic

reviews investigated different elements of mental health (positive versus negative mental health), both found convergence regarding the role of certain green space 'exposures'. The positive role of surrounding greenness, for example, was found in both systematic reviews and applied to both measures of mental distress (e.g., depression, anxiety), as well as mental wellbeing and life satisfaction. Evidence regarding access to green space is more difficult to untangle. While Gascon *et al*. (2015) rated the overall evidence as inadequate, with only half the reported studies finding an association, Houlden *et al*. (2018) rated it as limited. This discrepancy could be the result of several factors, including different tools for rating quality, different numbers and pool of included studies, and differences related to outcomes. Alternatively, this discrepancy might be the result of a selective green space effect. Given that both authors explored different dimensions of mental health, perhaps accessibility to green space is more important to positive elements than it is to negative elements.

Finally, visiting green spaces may also have important benefits for adult populations. This dimension of contact was explored in only one of the systematic reviews (Houlden *et al*., 2018), where positive associations were noted for quality of life, mental health, and GHQ scores.

For both child and adult populations, it seems that green space 'exposure' is related to mental health, though it exerts its effect differently. Evidence regarding emotional and behavioural difficulties is stronger and more consistent for children than adults, while evidence regarding wellbeing is stronger and more consistent for adults than children. In terms of overall mental health, as measured by the SDQ or GHQ, there is consistent evidence that both child and adult populations benefit from green space 'exposure'. Some important caveats, however, must be noted.

First, and most important, is that not all green space ‘exposures’ are created equal. By this, two related observations can be drawn: 1. Different ‘exposures’ logically implicate different underlying causal mechanisms; 2. The importance or relevance of any single ‘exposure’ might exert a different effect for different age groups and/or for mental health outcomes. The former observation is best exemplified through the conclusions of Tillmann *et al*. (2018). By stratifying their results based on different categories of ‘exposure’, they found that exposure based on incidental contact had far more significant versus non-significant associations than the other categories. Intuitively, these results make sense since this form of exposure involves some amount of engagement, and thus reduces some of the confounding influence of merely living near green space. The only other systematic review that investigated this dimension of contact was Houlden *et al*. (2018). While the authors did not present an overall ratio of significant to non-significant findings, they did find consistent results for ‘exposures’ that involved greater forms of engagement. The second observation speaks to the importance of understanding how a particular ‘exposure’ can exert different effects for different populations. Vanaken and Danckaerts (2018), for example, argued that green space accessibility showed stronger associations for younger children than older children and adolescents. They hypothesized that this could be the result of their smaller relative environmental circles. Mental health benefits for adolescents, on the other hand, were more strongly associated with neighbourhood surrounding greenness and green space quality.

2.4 Knowledge Gaps and Limitations in the Literature

Green space research continues to explore different ways that the natural environment can impact our health. Mental health research has grown substantially over the past decade,

investigating diverse ways that green spaces can impact child and adult populations. This research has explored several mental health outcomes, many of which focus on stress, depression, and well-being (Zhang *et al*., 2020). Outcomes related to substance use and addiction, on the other hand, have received little attention. An in-depth scoping of the literature, in tandem with a critical review of existing systematic reviews involving mental health, revealed one study that has investigated substance use outcomes among general populations and one additional study that investigated associations with substance use disorders. Despite an overall void of research in this area, the authors of one systematic review have suggested that addiction-related outcomes should be considered in future green space and mental health research (Vanaken and Danckaerts, 2018).

2.5 Theoretical Framework

Various theories have been proposed to explain the etiology and development of substance use behaviours. Cognitive-affective theories, social learning theories, social attachment theories, and intrapersonal theories have all contributed to an understanding of substance use. To organize and integrate this diverse theoretical body, and subsequently render it more practical, Petraitis *et al*. (1995) reviewed 14 of the most prominent theories within the field. Their review identified that some theories focus on single classes of risk factors, like the social-environment surrounding the behaviour, while others involve multiple classes of risk factors, like individual risk factors plus the social-environment. Recognizing the complexity that surrounds behavioural etiology, Petraitis *et al*. (1995) argue that substance use behaviour must be understood from an integrative approach. They acknowledge that such an approach must incorporate elements of: "(a) the broad social environment or cultural milieu surrounding the behaviour, (b) the more immediate social

situation or context in which the behaviour occurs, (c) the characteristics or dispositions of the person performing the behaviour, (d) the behaviour itself and closely related behaviours, and (e) the interaction among all" (p.79).

Rooted in this tradition, Petraitis *et al.* (1995) classify the causes of substance use along two dimensions: the *type of influence* and the *level of influence*. Each dimension is further broken down into three components, collectively forming a three-by-three matrix of potential causes. *Types of influence* that impact substance use include social and interpersonal influences (i.e., characteristics and behaviours of family and friends), cultural and attitudinal influences (i.e., personal values), and intrapersonal influences (i.e., personality characteristics, affective states, general behaviour). Influences can be further organized along a range of temporal patterns from which they exert their effect. These *levels of influence* are comprised of proximal, distal, and ultimate locations. Proximal influences, Petraitis *et al.* (1995) argue, comprise those characteristics that immediately precede behaviour. These variables tend to be the most predictive of a given behaviour but are usually influenced by other variables downstream. In this regard, proximal causes can be thought of as those causes closest in location to the behaviour of interest. Distal influences, on the other hand, represent more indirect influences for a given behaviour. Petraitis *et al.* (1995) argue that these types of influences tend to often be mediated by a series of proximal causes. Finally, those causes furthest downstream, or as Petraitis *et al.* (1995) describe as exogenous roots, are ultimate influences. These influences shape behaviour through the external influence of broad social and opportunity structures. The quality of one's school or living in a neighbourhood with high levels of crime, are examples cited by Petraitis *et al.* (1995), that in turn shape decision-making processes and subsequent behaviour. These levels

of influence are ultimate in the sense that their presence initiates a sequence of events and behaviours from which all future behaviour can ultimately be traced.

In addition to providing a more nuanced theoretical understanding of substance use, Petraitis *et al.* (1995) highlight gaps within the substance use theoretical literature. They argue that important concepts have been ignored, like gender and ethnicity, that most theories have remained simplistic in their organization of constructs (e.g., effect modification has received little attention), and finally, they propose that different substances might have different aetiologies.

From a practical standpoint, the work of Petraitis *et al.* (1995) highlights many challenges to substance use research. Empirical investigation ought to be informed by a cohesive theoretical foundation, yet current theories remain variegated and disparate. Exploratory research interested in substance use patterns, as opposed to strictly etiology, can make amends with these issues by appealing to an integrative approach. Such an approach acknowledges the broad theoretical strokes of the field, without being restricted to the limits of any one theory. The following variables and constructs used for this thesis adhere to this approach. Recognizing the contributions of Petraitis *et al.* (1995), various influences across proximal, distal, and ultimate levels were selected for analysis. Constructs were chosen based on their demonstrated links with substance use behaviour as evidenced in the wider literature.

CHAPTER 3: METHODS

3 Introduction

This chapter describes the methodology used for the study. Section 3.1 describes the two data sources, the Canadian Community Health Survey and the Canadian Urban Environmental Health Research Consortium, section 3.2 describes the analytic sample, section 3.3 describes correlates of substance use, and section 3.4-3.6 describes statistical procedures for working with this data.

3.1 Data Sources

3.1.1 Canadian Community Health Survey

The Canadian Community Health Survey (CCHS) is a national survey, conducted yearly, that covers individuals 12 years and over across all provinces and territories. The survey collects information on a series of outcomes with the aim of understanding health system utilization, health status, and determinants of health. Except for a few groups—i.e., some Indigenous groups, members of the Canadian Forces, children in foster care, and institutionalized individuals—the survey is designed to capture a representative snapshot of the Canadian population at large.

Survey questions cover four broad domains and are collected via computer-assisted in-person and telephone interviews. Core content (i.e., most questions) remains stable from cycle to cycle, while optional content varies at the discretion of the provinces and territories.

3.1.1.1 Sampling

With the goal of providing detailed information at the Health Region level, the CCHS targets a sample based on two-year time periods. The two-year target sample is 130,000 participants,

120,000 of whom are adults and 10,000 of whom are children. Within this design, data are collected annually, with each two-year sample constituting a single cycle. Sampling follows a multi-stage strategy, with allocation informed by both the total provincial population and the respective Health Regions (HRs). Two different sampling frames are used to generate the sample, one for children (aged 12 – 17) and one for adults (aged 18+). The former relies on the Canadian Child Tax Benefit frame and the latter on an area frame informed by the Labour Force Survey.

This study used data from three years of the Canadian Community Health Survey (2016, 2017, 2018). All data that was used originated from core-content that did not vary between cycles.

3.1.2 Canadian Urban Environmental Health Research Consortium

The second source of data for this project comes from the Canadian Urban Environmental Health Research Consortium (CANUE). CANUE is a research consortium made up of interdisciplinary members in the areas of environmental health research, health policy, and urban design and planning. CANUE provides researchers access to a variety of environmental data at practical geographic scales such as postal codes. Datasets include measures of greenness, air quality, and weather that covers all, or most of Canada. This study uses the Landsat annual greenness dataset. This dataset uses top of atmosphere reflectance data, using the Landsat 5 and Landsat 8 satellites, to estimate average annual greenness for any given postal code. This dataset includes annual estimates from 1980 to 2019 and contains values for 99.9% of Canadian postal codes.

3.2 Analytic Sample

This study investigates the relationship between residential greenness and substance use in a sample of urban transitional aged youth (TAY). Restricting the sample to this population confers both etiological and methodological benefits. TAY roughly encompasses the transition from childhood to adulthood (ages 15-25) and includes serval developmental milestones intricately linked to substance use and abuse (Bukstein, 2017; Dariotis & Chen, 2020; Wilens *et al.*, 2013). Given that these years are marked by experimentation and initiation into substance use, it provides a rich context for exploring proximal and distal causes of substance use. Similarly, by focussing on a relatively young sample, some of the confounding influence associated with past-substance use can be mitigated. In older age ranges, non-users represent a diverse group of abstainers and former users, which can influence results if not accounted for.

This study was also restricted to urban locations to limit the misclassification of residential greenness. Residential greenness is measured in reference to a single coordinate within each postal-code polygon, which makes misclassification more likely for sparsely populated rural areas (Healy & Gilliland, 2012).

3.3 Measurement Instruments

This study investigates the relationship between residential greenness and substance use in a cohort of transitional aged youth between 2016 and 2018. The following section will describe each variable that was included in the analysis and explain how it was measured.

3.3.1 Substance Use

Substance use patterns are the primary outcome of this study. Following national trends, patterns of substance use for alcohol, tobacco, and marijuana were explored. Data for each outcome were obtained from the CCHS in conjunction with a series of questions that pertain to both frequency of use and quantity of use.

Alcohol use was explored in relation to two different outcomes, past year frequency of use and past year binge drinking frequency. For alcohol frequency, individuals were asked how often, over the past 12 months, they drank alcoholic beverages. Responses were measured across seven categories that ranged from less than once per month to daily. For binge drinking frequency, individuals were asked how often they consumed more than 5 drinks (male) or 4 drinks (female) on a single occasion. Responses for this variable were measured across six categories that ranged from never to more than once per week. Given extreme variation in sample size across categories, including small cell counts, the categories for alcohol frequency and binge drinking were collapsed into never, less than monthly, monthly, and weekly.

Tobacco use was explored in relation to past year frequency and quantity of use. Individuals who identified as current or occasional smokers were asked how many cigarettes they smoke per day. These individuals were then classified as light, moderate, or heavy users based on Government of Canada definitions. Light smokers included 1-10 cigarettes/day, moderate included 11-19 cigarettes/day, and heavy included 20+ cigarettes/day.

Marijuana/hash was explored in relation to past year frequency of use. Individuals who indicated any past year use were asked how often they used over the previous year. Responses were measured across five categories that ranged from less than once per month to daily. Given small cell counts, categories were collapsed into up to three times per month, weekly, and daily.

Information regarding the quantity of marijuana/hash used was not available, as the CCHS does not collect information on this variable.

3.3.2 Green Space

Green space is the focal independent variable of the study. Within the literature, green space has been measured in multiple ways with no clear indication of which measure(s) are best. A popular form of green space measurement uses the Normalized Difference Vegetation Index (NDVI) to describe surrounding greenness. NDVI is a measure of vegetation density based on differences in near-infrared and red light (Rhew *et al.*, 2011). Values of NDVI range from –1 to 1, indicating a continuum of possible types of land cover. Negative values imply an absence of vegetation (e.g., water, snow), while positive values imply increasing levels of greenness. When compared against expert ratings and land-cover and land-use characteristics, NDVI has been demonstrated to be a valid measure of urban greenness and a practical measure for population-level research (Gascon *et al*., 2016; Rhew *et al*., 2011).

NDVI data for this study was obtained from CANUE. The Landsat-Annual greenness dataset provides NDVI estimates obtained from the Landsat 5 and Landsat 8 satellites. These satellites provide an annual mean NDVI estimate for each postal code with a spatial resolution of 30m. Each estimate is linked to a single coordinate (i.e., centroid) within each postal code area polygon. Quality of the data was ensured by adjusting for cloud contamination and by masking water features (CANUE, 2020). To limit potential exposure misclassification that results from using address proxies such as postal codes, the following study utilizes a buffer zone of 1000m around each centroid. While many authors have elected to use buffers as small as 100m to 500m, research has indicated that misclassification could be very large if smaller buffer sizes are used

(Healy & Gilliland, 2012). Similarly, since misclassification is likely to be exacerbated for rural areas, the current study is limited to urban areas. Following other research, NDVI was categorized into quartiles and analyzed as a categorical variable in the statistical models (Barreto *et al*., 2019; McMorris *et al*., 2015; Song *et al*., 2019; Srugo *et al*., 2019).

3.3.3 Socio-demographic Factors

3.3.3.01 Sex

Substance use patterns vary substantially by gender. Men tend to initiate substance use earlier, use substances more frequently, and consume more compared to women (Fillmore, 1987; Leatherdale, & Burkhalter, 2012; McHugh *et al*., 2018; Nolen-Hoeksema, 2004). To account for the influence of this sex gap, sex is included in the following study and takes a binary form that includes male and female.

3.3.3.02 Age

Age is an important factor for understanding substance use. Alcohol use, for example, has been shown to vary considerably with age, with consumption rising sharply during adolescence, peaking in early adulthood, before declining and levelling off in later life (Britton *et al*., 2015; Danielsson et al., 2010; Maggs & Schulenberg, 2004). Research on tobacco trajectories has tended to focus on early adolescents and young adulthood and has also demonstrated patterns of escalation through adolescence, before leveling-off in young adulthood (Jackson *et al*., 2002). Research on marijuana use trajectories has mirrored that of alcohol for the most part. One notable difference, however, is that several marijuana use trajectories have displayed patterns of

decreasing use (Nelson *et al*., 2015). Age was included as a categorical variable with the following breakdown: 15-18 years old, 19-21 years old, 22-25 years old.

3.3.3.03 Education

Educational attainment is an important marker of SES with demonstrable links to substance use (Campbell *et al*., 2018; Seabrook & Avison, 2012). Research in this area has indicated that the relationship between education and substance use varies by age group. Among adolescents, for example, research shows a strong association with both individual and parental education, with higher education relating to less risky consumption (Casswell *et al.*, 2003; Goodman & Huang, 2002; Huerta & Borgonovi, 2010; Reid *et al.*, 2010 Wills *et al.,* 1995). The CCHS does not measure parental educational attainment, so individual educational attainment was selected instead. This variable was grouped into three categories according to highest level of attainment: those with less than a secondary school diploma, those with a secondary school diploma, and those with a post-secondary certificate, diploma or degree.

3.3.3.04 Ethnicity

Patterns of substance use have been documented to vary substantially by race. Across the life course, White people use alcohol and tobacco more frequently and at higher levels than Black people (Evans *et al*., 2017; Keyes *et al*., 2015; Zapolski *et al*., 2014). Less research has investigated racial differences in the use of marijuana. Limited research suggests that marijuana use is similar across Black and White groups, with Black groups having higher levels of marijuana use disorder (Keyes *et al*., 2015 ; Pacek *et al*., 2012). Among young adults, White people have been found to have higher levels of substance use disorders (Vasilenko *et al*., 2017).

Given the small sample size across non-White subgroups, the following study included race as a binary variable based on the self-identification of respondents as White or non-White.

3.3.3.05 Immigration Status

Substance use patterns can also vary by immigration status. Following the well-established 'healthy immigrant effect', immigrants have been found to have less substance use and abuse problems than native born residents (Bui & Bui, 2013; Johnson *et al*., 2002; Salas-Wright *et al*., 2014). Respondents of the CCHS were asked whether they are now, or ever have been, a landed immigrant in Canada. Responses were coded as yes/no and included in the statistical model as a binary variable.

3.3.3.06 Employment Status

Substance use varies by employment status. Individuals who are unemployed tend to have greater risks for risky alcohol, tobacco, and marijuana use, compared to their employed counterparts (Compton *et al*., 2014; Henkel, 2011; Lee *et al*., 2015). To account for potential confounding, employment status is included as a covariate in the statistical models. Individuals were categorized as either students, employed, unemployed, or other.

3.3.3.07 Sexual Orientation

Substance use behaviour also varies with sexual orientation. In general, research suggests that non-heterosexual individuals have an increased risk of substance use and abuse, and that bisexual individuals might have the highest risks among non-heterosexual orientations (Ford & Jasinski, 2006; Green & Feinstein, 2012; Marshal *et al*., 2008; McCabe *et al*., 2009). Sexual orientation

was included in the present study as a categorical variable with three categories, heterosexual, homosexual, and bisexual.

3.3.3.08 Household Income

Household Income was included in the analysis as a marker for SES. Research has consistently documented an association between household income and substance use. Alcohol and marijuana use have been shown to be highest among the highest categories of household income, while tobacco use has been shown to be more concentrated in the lowest categories of income (Hanson & Chen, 2007; King *et al*., 2012; Melotti *et al*., 2011; Patrick *et al*, 2012).

3.3.3.09 Urbanicity

A large body of research has consistently documented variation in substance use between rural and urban dwellers. Much of this research has found that rural adolescents are more likely to use and abuse various substances compared to their urban counterparts (Lambert *et al.*, 2008; McInnis & Young, 2015). More specifically, rural youth are more likely to use alcohol and tobacco, while urban youth are more likely to use illicit drugs and marijuana (Hanson *et al.*, 2008; Warren *et al.*, 2017). The use of an urban-rural dichotomy, however, is crude and does not distinguish between different categories of urban. The present study, therefore, includes a variable for urbanicity that distinguishes between small, medium, and large population centers. Following Statistics Canada's recommendation, small centers were defined as populations of 1,000-29,000, medium populations of 30,000-99,000, and large centers from 100,000 and up.

3.3.3.10 Marital Status

Substance use behaviour varies by marital status. Single, divorced, and separated individuals use alcohol, marijuana, and tobacco more frequently and in greater quantity than their married counterparts (Jang *et al*., 2018; Liang, 2011; Merline *et al*., 2004; Seabrook *et al*., 2017). Marital status data for this study uses three categories: married/common-law, widowed/divorced/separated, and single.

3.3.4 Health-related Factors

3.3.4.1 Stress

Substance use is a common coping mechanism for dealing with stress, especially among adolescents (Leonard *et al*., 2015; Wagner, 1993; Wagner *et al*., 1999). To account for its potential confounding influence, stress was included in the statistical model. Stress was measured on an ordinal scale by asking participants about the levels of stress they encounter in a usual day. Responses were measured on a five-point scale that ranged from ‘not at all stressful’ to ‘extremely stressful’.

3.3.4.2 Body Mass Index (BMI)

Research that has investigated associations between BMI and substance use have noted inverse relationships between being overweight and substance use (Bluml *et al.*, 2012; Kleiner *et al.*, 2004; Warren *et al.*, 2005). These studies support the broader hypothesis that food consumption and drug use may compete for similar reward sites in the brain (Bluml *et al.*, 2012). To account for potential confounding, BMI was included as a covariate and categorized into underweight,

normal weight, overweight, and obese, according to the Centre for Disease Control and Prevention (CDC, 2020).

3.3.4.3 Self Perceived Health

Previous research has identified self-perceived health as a correlate of substance use (Johnson & Richter, 2002; Moral-García *et al*., 2020; Peggy *et al*., 2004; Rius *et al*., 2004). Among adolescents, low perceived health is associated with elevated alcohol and tobacco use (Johnson & Richter, 2002; Moral-García *et al*., 2020; Rius *et al*., 2004). Self-perceived health is included in the present study as a categorical variable with five categories: poor, fair, good, very good, excellent.

3.3.4.4 Mental Disorders

Mental disorders co-occur with substance use disorders at an alarmingly high rate. Strong associations have been noted between depression, anxiety, mood, conduct, and antisocial personality disorders with substance use disorders (Currie *et al*., 2016; Jané-Llopis & Matytsina, 2006; Merikangas *et al*., 1998; Seabrook & Avison, 2010). The temporal sequence of onset varies considerably. Evidence suggests that anxiety disorders tend to precede substance use disorders, while substance use disorders tend to precede depressive disorders (Jané-Llopis & Matytsina, 2006; Merikangas *et al*., 1998). For this study, two binary indicators for mental disorders were included. The first pertains to mood disorders (depression, bipolar, mania, dysthymia) and the second anxiety disorders (phobia, OCD, panic). The indication of either disorder was based on self-report of a physician diagnosis.

3.3.4.5 Other Substance Use

Research has demonstrated that individuals who use one substance are much more likely to use another (Conway *et al*., 2013; Moss *et al*., 2013). This has been especially pronounced amongst adolescents, where the prevalence of polysubstance use has been on the rise (Zuckermann *et al*., 2018). To account for polysubstance use, each model contains two binary covariates that represent either smoking status, alcohol use status, or marijuana use status (each pattern of covariates depend on the outcome under investigation).

3.4 Statistical Analyses

All Statistical analyses were conducted in Stata IC 15.

3.4.1 Model 1: Residential Greenness and Alcohol Use

The first model (1.A) explored the relationship between residential greenness and drinking frequency over the past twelve months. Multinomial regression was used to compare three thresholds (less than monthly, monthly, weekly) of drinking versus non-drinking for individuals in the greenest versus least green quartiles. Covariates were chosen based on their hypothesized associations with alcohol use and included: age, sex, educational attainment, ethnicity, immigration status, mental health, employment status, marital status, urbanicity, household income, self-perceived health, self-perceived stress, BMI, sexual orientation, tobacco use, and marijuana use.

Since this model assessed separate categories of alcohol use, a second, cruder model (1.B) was created to assess the overall relationship between *any* category of drinking and residential greenness. This model utilized a binary outcome for past year drinking with the same covariates as the multinomial model.

3.4.2 Model 2: Residential Greenness and Binge Drinking

The second model (2.A) assessed the relationship between residential greenness and binge drinking over the past twelve months. Like model one, multinomial regression was used to compare three thresholds (less than monthly, monthly, weekly) of binge drinking versus non-binge drinking for individuals in the greenest versus least green quartiles.

Again, a second, cruder model (2.B) was created to assess the overall relationship between *any* category of binge drinking and residential greenness. This model utilized a binary outcome for past year binge drinking with the same covariates as the multinomial model.

3.4.3 Model 3: Residential Greenness and Tobacco Use

The third model (3.A) investigated the relationship between residential greenness and tobacco over the past twelve months. Multinomial regression was used to compare three thresholds (low, moderate, heavy) of tobacco use versus non-tobacco use for individuals in the greenest versus least green quartiles. Covariates included: age, sex, educational attainment, ethnicity, immigration status, mental health, employment status, marital status, urbanicity, household income, self-perceived health, self-perceived stress, BMI, sexual orientation, alcohol use, and marijuana use.

Again, a third, cruder model (3.B) was created to assess the overall relationship between *any* category of tobacco use and residential greenness. This model utilized a binary outcome for past year tobacco use with the same covariates as the multinomial model.

3.4.4 Model 4: Residential Greenness and Marijuana Use

The fourth model (4.A) explored the relationship between residential greenness and marijuana use over the past twelve months. Multinomial regression was used to compare three thresholds (less than monthly, monthly, weekly) of marijuana use versus non-marijuana use for individuals in the greenest versus least green quartiles. Covariates included: age, sex, educational attainment, ethnicity, immigration status, mental health, employment status, marital status, urbanicity, household income, self-perceived health, self-perceived stress, BMI, sexual orientation, tobacco and alcohol use.

Again, a fourth, cruder model (4.B) was created to assess the overall relationship between *any* category of tobacco use and residential greenness. This model utilized a binary outcome for past year tobacco use with the same covariates as the multinomial model.

3.5 Missing Data

Several variables had some level of missingness, though it remained quite small (<1% per variable). The two variables with the most missingness were BMI (5% missing) and sexual orientation (3% missing). Overall missingness for each model ranged from 12% to 13%. Patterns of missingness were explored for each of the four models and 'Little's MCAR test' was used to evaluate the assumption of missing completely at random (Li, 2013). The MCAR assumption was satisfied, and complete case analysis was used for each of the models.

3.6 Collinearity

Collinearity was evaluated for each model through the calculation of a variance inflation factor. All VIF's were less than 2.5 indicating little concern about collinearity.

CHAPTER 4: RESULTS

4 Introduction

This chapter describes the overall composition of the sample and provides results for the descriptive and inferential statistical analyses. Section 4.1 describes the sample, 4.2 describes the prevalence of polysubstance use, and 4.3 presents multinomial and logistic regression results.

4.1 Sample Characteristics

The entire sample included 14,070 transitional aged youth living in urban areas. The average NDVI for the total sample was 0.42 and ranged from an average of 0.29 in the least green quartile to an average of 0.56 in the greenest quartile. A complete description of descriptive statistics for the total sample and each respective greenness quartile is presented in Table 1.

Table 1: Sample Characteristics (Overall and by Greenness Quartile)

	mean ± sd, n (%)				
		Greenness Quartile			
Characteristic	**Total**	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**
NDVI	0.42 ± .10	0.29 ± .06	0.38 ± .02	0.45 ± .02	0.56 ± .05
Sex					
male	7,016 (49.9)	1,960 (49.7)	1,659 (50.2)	1,805 (49.6)	1,592 (49.9)
female	7,054 (50.1)	1,983 (50.3)	1,643 (49.8)	1,832 (50.4)	1,596 (50.1)
Age	19.9 ± 3.3	20.5 ±3.3	20.0 ±3.3	19.7 ±3.3	19.3 ±3.2
Urban					
small	3,549 (25.2)	708 (18)	649 (19.6)	904 (24.9)	1,288 (40.4)
medium	2,235 (15.8)	533 (13.5)	518 (15.7)	662 (18.2)	522 (16.4)
large	8,286 (58.9)	2,702 (68.5)	2,135 (64.7)	2,071(56.9)	1,378 (43.2)
Race					
white	9,435 (67.8)	2,177 (55.9)	2,017 (61.7)	2,606 (72.6)	2,635 (83.3)
non-white	4,483 (32.2)	1,720 (44.1)	1,251 (38.3)	985 (27.4)	527 (16.7)
Immigrant					
yes	2402 (17.2)	1,004 (25.7)	679 (20.7)	468 (13)	251 (7.9)
no	11,537 (82.8)	2,899 (74.3)	2,597 (79.3)	3,130 (87)	2,911 (92.1)
Education					

less than high-school	5,043 (36)	1,175 (30)	1,142 (34.7)	1,403 (38.8)	1,323 (41.7)
high-school diploma	4,964 (35.5)	1,469 (37.5)	1,211 (36.8)	1,229 (34)	1,055 (33.2)
post-secondary	3,988 (28.5)	1,274 (32.5)	934 (28.5)	985 (27.2)	795 (25.1)
Marital Status					
married/ common law	1,595 (11.4)	520 (13.2)	371 (11.3)	388 (10.7)	316 (10)
single	12,404 (88.6)	3,408 (86.8)	2,911 (88.7)	3,230 (89.3)	2,855 (90)
Mood Disorder					
yes	1,503 (10.7)	438 (11.1)	362 (11)	400 (11)	303 (9.5)
no	12,533 (89.3)	3,498 (88.9)	2,929 (89)	3,224 (89)	2,882 (90.5)
Anxiety Disorder					
yes	1,961 (14)	524 (13.3)	462 (14)	499 (13.8)	476 (15)
no	12,079 (86)	3,413 (86.7)	2,830 (86)	3,131 (86.2)	2,705 (85)
Self Perceived Health	3.9 ± .9	3.88 ± .9	3.89 ± .92	3.92 ± .9	3.94 ± .88
Self Perceived Stress	3.23 ± .92	3.20 ± .93	3.24 ± .92	3.22 ± .91	3.25 ± 92
Employment					
employed	5,487 (39.4)	1,703 (43.6)	1,314 (40.3)	1,342 (37.3)	1,128 (35.8)
student	6,548 (47.1)	1,700 (43.6)	1,492 (45.7)	1,739 (48.3)	1,617 (51.3)
unemployed	678 (4.9)	202 (5.2)	169 (5.2)	173 (4.8)	134 (4.3)
other	1,197 (8.6)	296 (7.6)	287 (8.8)	343 (9.5)	271 (8.6)
Household Income	103,804 ± 134,072.4	86,185.81 ± 83,904.8	102,206.3 ± 139,115.6	111,037.1± 175,110.9	118,997.6± 122,221.0
Sexual Orientation					
heterosexual	12,269 (92.3)	3,433 (91.4)	2,868 (92.3)	3,167 (92.8)	2,801 (92.9)
homosexual	319 (2.4)	103 (2.7)	75 (2.4)	68 (2)	73 (2.4)
bisexual	705 (5.3)	221 (5.9)	165 (5.3)	179 (5.2)	140 (4.6)
BMI	23.7 ± 5	23.7 ± 4.8	23.9 ± 5.3	23.7 ± 4.9	23.6± 4.9
	n= 14,070	n= 3,943	n= 3,302	n= 3,637	n= 3,188

4.2 Substance Use and Polysubstance Use

The first objective of this thesis was to describe the prevalence of substance use behaviour among transitional aged youth. Past year alcohol use had the highest prevalence (74%), followed by binge drinking (53%), tobacco use (16%), and marijuana use (11%). Polysubstance use was

very high, with most substance users indicating use of more than one substance. Overall, 93% of smokers and 95% of marijuana users reported past year alcohol use and 81% of smokers and 82% of marijuana users indicated some level of past-year binge drinking. In addition to the individual substance use prevalence, Table 2 displays the co-occurrence of dual substance use while Table 3 describes specific patterns of polysubstance use.

Table 2: Comorbid Substance Use

		n (column %)	
	alcohol	***marijuana***	***smoke***
binge	7431 (72.3)	1221 (82.3)	1888 (81.1)
alcohol		1426 (95.2)	2172 (93.3)
marijuana			524 (22.5)

Table 3: Polysubstance Use Patterns

SUBSTANCE USE PATTERN	*n (total sample %)*
nothing	3,339 (24.7)
smoke only	125 (0.9)
marijuana only	44 (0.3)
alcohol only	2,392 (17.4)
alcohol + binge only	4,744 (34.4)
alcohol + binge + smoke only	1,422 (10.3)
alcohol + binge + marijuana only	772 (5.6)
alcohol + binge + marijuana +smoke	449 (3.3)

4.3 Adjusted Models

4.3.1 Past Year Alcohol Use

Model 1A explored past year alcohol use frequency at different levels of residential greenness using multinomial regression. In the adjusted model, there was no statistically significant

differences between past year drinking frequency and residential greenness. Significant associations, however, were noted for many of the other covariates. Smoking and marijuana use were consistently associated with increased odds in drinking versus non-drinking across alcohol frequency categories. Other covariates with significant associations across outcomes include: urbanicity, age, educational attainment, race, immigration status, and self-perceived health.

Table 4: Model 1(A) Residential Greenness and Alcohol Frequency

Characteristic	**Rarely**			**Monthly**			**Weekly**		
	Odds Ratio	95% C.I.		Odds Ratio	95% C.I.		Odds Ratio	95% C.I.	
Residential Greenness									
Quartile 1	*reference*			*reference*			*reference*		
Quartile 2	1.02	0.87	1.20	0.95	0.81	1.12	0.92	0.77	1.09
Quartile 3	1.08	0.92	1.27	1.00	0.85	1.17	0.95	0.80	1.13
Quartile 4	1.18	0.99	1.40	1.18	1.00	1.40	1.07	0.89	1.29
Urban									
small	*reference*			*reference*			*reference*		
medium	0.79*	0.66	0.95	.70**	0.58	0.84	0.67**	0.55	0.83
large	0.77**	0.66	0.88	.76**	0.65	0.88	0.83*	0.71	0.98
BMI									
underweight	*reference*								
normal	1.32**	1.10	1.59	1.80**	1.47	2.21	1.67**	1.32	2.12
overweight	1.21	0.97	1.51	1.68**	1.33	2.12	1.34*	1.03	1.76
obese	1.34*	1.04	1.73	1.58**	1.20	2.07	0.93	0.69	1.27
Age									
15-18	*reference*			*reference*			*reference*		
19-21	1.46**	1.20	1.78	2.41**	1.99	2.91	4.63**	3.73	5.76
22-25	1.79**	1.44	2.23	2.59**	2.09	3.22	6.73**	5.31	8.53
Smoker									
no	*reference*			*reference*			*reference*		
yes	2.53**	2.01	3.19	3.94**	3.15	4.93	7.68**	6.11	9.64
Marijuana user									
no	*reference*			*reference*			*reference*		
yes	3.90**	2.88	5.28	6.40**	4.76	8.60	8.85**	6.54	11.97
Marital Status									
single	*reference*			*reference*			*reference*		

married/common law	1.19	0.93	1.50	1.03	0.82	1.30	0.97	0.77	1.22
Employment									
employed	*reference*			*reference*			*reference*		
student	0.78**	0.67	0.91	0.69**	0.60	0.81	0.57**	0.49	0.67
unemployed	0.94	0.70	1.26	0.71*	0.53	0.94	0.50**	0.37	0.68
other	0.72**	0.57	0.90	0.45**	0.35	0.57	0.33**	0.26	0.43
Sex									
female	*reference*			*reference*			*reference*		
male	0.89*	0.79	1.00	1.05	0.93	1.18	1.69**	1.48	1.92
Education									
less than high-school	*reference*			*reference*			*reference*		
high-school diploma	2.04**	1.73	2.41	3.66**	3.09	4.33	5.79**	4.74	7.07
post-secondary	1.62**	1.29	2.04	3.76**	3.01	4.71	8.13**	6.34	10.41
Race									
white	*reference*			*reference*			*reference*		
Non-white	0.53**	0.46	0.60	0.41**	0.36	0.47	0.25**	0.22	0.30
Immigrant									
no	*reference*			*reference*			*reference*		
yes	0.63**	0.53	0.74	0.50**	0.42	0.59	0.37**	0.30	0.44
Household Income									
decile 1	*reference*			*reference*			*reference*		
decile 2	0.81	0.62	1.06	0.79	0.60	1.02	0.86	0.65	1.14
decile 3	0.83	0.63	1.08	0.74*	0.57	0.97	0.80	0.60	1.07
decile 4	0.82	0.63	1.06	0.76*	0.58	0.99	0.96	0.72	1.27
decile 5	0.80	0.62	1.04	0.74*	0.57	0.96	0.91	0.68	1.20
decile 6	0.84	0.65	1.09	0.81	0.63	1.05	1.05	0.79	1.39
decile 7	0.96	0.74	1.24	0.97	0.75	1.26	1.09	0.82	1.45
decile 8	0.94	0.72	1.22	1.04	0.80	1.35	1.13	0.85	1.51
decile 9	0.92	0.71	1.19	0.93	0.72	1.21	1.09	0.82	1.45
decile 10	0.92	0.70	1.21	1.09	0.83	1.42	1.57	1.18	2.10
Self Perceived Stress									

extremely stressed	*reference*			*reference*			*reference*		
quite a bit stressed	1.33	0.85	2.08	1.71*	1.09	2.69	1.55	0.97	2.47
a bit stressed	1.25	0.81	1.92	1.37	0.88	2.13	1.13	0.72	1.78
not very stressed	1.13	0.72	1.75	1.14	0.73	1.78	0.87	0.55	1.38
not at all stressed	0.89	0.56	1.41	0.86	0.54	1.38	0.70	0.43	1.14
Self Perceived Health									
poor	*reference*			*reference*			*reference*		
fair	3.04**	1.42	6.49	3.12**	1.39	7.02	2.72*	1.18	6.24
good	2.63**	1.27	5.43	3.81**	1.75	8.28	2.90**	1.31	6.42
very Good	3.02**	1.46	6.27	4.80**	2.20	10.45	4.26**	1.92	9.45
excellent	2.50*	1.20	5.22	4.19**	1.91	9.16	3.89**	1.74	8.68
Sexual Orientation									
heterosexual	*reference*			*reference*			*reference*		
homosexual	1.02	0.68	1.54	1.21	0.81	1.80	1.05	0.69	1.61
bisexual	1.20	0.91	1.58	1.28	0.97	1.70	1.41	1.04	1.91
Anxiety Disorder									
no	*reference*			*reference*			*reference*		
yes	1.03	0.83	1.28	0.93	0.75	1.16	0.94	0.75	1.19
Mood Disorder									
no	*reference*			*reference*			*reference*		
yes	1.20	0.93	1.54	1.07	0.83	1.39	1.01	0.77	1.33

[1]reference category for outcome = 'Never'

[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Model 1B explored the overall association between past-year drinking and residential greenness through binary logistic regression. This model collapsed active categories of drinking and compared the odds of being a past-year drinker, versus non-drinker, across greenness quartiles. Like model 1A, there was no statistically significant difference between the greenest versus least green quartile.

Other covariates that were significantly associated with alcohol use include: urbanicity, BMI, age, smoking, marijuana use, employment status, educational attainment, race, immigration status, self-perceived health, and having a bisexual orientation.

Table 5: Model 1(B) Residential Greenness and Alcohol Use (Yes/No)

Characteristic	**Odds Ratio**	**95% C.I.**	
Residential Greenness			
Quartile 1	*reference*		
Quartile 2	0.97	0.85	1.11
Quartile 3	1.01	0.88	1.16
Quartile 4	1.14	0.99	1.32
Urban			
small	*reference*		
medium	0.74**	0.63	0.87
large	0.78**	0.69	0.89
BMI			
underweight	*reference*		
normal	1.54**	1.31	1.81
overweight	1.39**	1.15	1.69
obese	1.31*	1.04	1.64
Age			
15-18	*reference*		
19-21	2.25**	1.90	2.66
22-25	2.76**	2.28	3.35
Smoker			
no	*reference*		
yes	3.94**	3.20	4.85
Marijuana user			

no	*reference*		
yes	5.66**	4.27	7.50
Marital Status			
single	*reference*		
married/common law	1.05	0.85	1.29
Employment			
employed	*reference*		
student	0.68**	0.60	0.78
unemployed	0.71*	0.55	0.92
other	0.50**	0.41	0.61
Sex			
female	*reference*		
male	1.08	0.97	1.19
Education			
less than high-school	*reference*		
high-school diploma	3.03**	2.62	3.51
post-secondary	3.28**	2.68	4.00
Race			
white	*reference*		
non-white	0.41**	0.37	0.47
Immigrant			
no	*reference*		
yes	0.51**	0.44	0.58
Household Income			
decile 1	*reference*		
decile 2	0.83	0.65	1.04
decile 3	0.82	0.64	1.03
decile 4	0.84	0.67	1.06
decile 5	0.82	0.65	1.03
decile 6	0.89	0.71	1.12
decile 7	1.02	0.81	1.28
decile 8	1.04	0.82	1.31
decile 9	0.98	0.78	1.23
decile 10	1.11	0.88	1.40
Self Perceived Stress			
extremely stressed	*reference*		
quite a bit stressed	1.53*	1.04	2.26
a bit stressed	1.28	0.87	1.87
not very stressed	1.08	0.73	1.58
not at all stressed	0.84	0.56	1.26
Self Perceived Health			
poor	*reference*		
fair	2.99**	1.55	5.76

good	3.07**	1.64	5.72
very Good	3.85**	2.06	7.20
excellent	3.32**	1.77	6.23
Sexual Orientation			
heterosexual	*reference*		
homosexual	1.12	0.78	1.59
bisexual	1.29*	1.01	1.65
Anxiety Disorder			
no	*reference*		
yes	0.96	0.79	1.17
Mood Disorder			
no	*reference*		
yes	1.12	0.89	1.41

[1]reference category for outcome = 'Never'
[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

4.3.2 Past Year Binge Drinking

Model 2A explored past year binge drinking frequency at different levels of residential greenness using multinomial regression. In the adjusted model, there was no statistically significant differences between past year binge drinking frequency and residential greenness in the greenest versus least green quartile. There were, however, statistically significant results for the second and third greenest quartiles. In quartile three, there was an 18% reduction (OR .82; 95% C.I .70, .95) in the odds of monthly (versus never) binge drinking compared to quartile one, and in quartile two, individuals had lower odds of both monthly (OR .83; 95% C.I .71, .98) and weekly (OR .78; 95% C.I .62, .97) binge drinking, compared to quartile one.

Both smokers and marijuana users had increased odds of all levels of binge drinking, while holding the other covariates constant. Smoking was associated with nearly a twelve-fold increase in the odds of weekly binge drinking (OR 11.58; 95% C.I 9.47, 14.16), and marijuana use was associated with approximately a five-fold increase in the odds of weekly binge drinking (OR 5.19; 95% C.I 4.13, 6.53). Sex also showed an interesting pattern of association and was

only significant in the weekly versus never category, with men having a 72% increase in the odds of binge drinking (OR 1.72; 95% C.I 1.45, 2.04). Other covariates with significant associations across binge drinking categories include: urbanity, age, marital-status, employment, education, race, and immigration-status.

Table 6: Model 2 (A) Residential Greenness and Binge Drinking Frequency

Characteristic	**Rarely**			**Monthly**			**Weekly**		
	Odds Ratio	95% C.I.		Odds Ratio	95% C.I.		Odds Ratio	95% C.I.	
Residential Greenness									
Quartile 1	*reference*			*reference*			*reference*		
Quartile 2	0.96	0.84	1.09	0.84*	0.71	0.98	0.78*	0.62	0.97
Quartile 3	0.94	0.83	1.07	0.82*	0.70	0.95	0.81	0.65	1.00
Quartile 4	1.06	0.93	1.22	0.93	0.79	1.10	0.81	0.64	1.03
Urban									
small	*reference*			*reference*			*reference*		
medium	0.78**	0.67	0.91	0.62**	0.52	0.75	0.65**	0.51	0.84
large	0.78**	0.69	0.88	0.67**	0.59	0.77	0.61**	0.50	0.74
BMI									
underweight	*reference*			*reference*			*reference*		
normal	1.36**	1.14	1.62	2.01**	1.57	2.57	1.77*	1.22	2.57
overweight	1.48**	1.21	1.80	1.99**	1.52	2.60	1.77*	1.19	2.63
obese	1.27*	1.01	1.58	1.52**	1.13	2.04	1.32	0.86	2.03
Age									
15-18	*reference*			*reference*			*reference*		
19-21	1.90**	1.63	2.22	2.29**	1.90	2.76	4.80**	3.55	6.48
22-25	1.91**	1.62	2.26	2.17**	1.77	2.65	5.03**	3.67	6.89
Smoker									
no	*reference*			*reference*			*reference*		
yes	3.04**	2.60	3.56	5.51**	4.66	6.51	11.58**	9.47	14.16
Marijuana user									
no	*reference*			*reference*			*reference*		
yes	2.82**	2.36	3.37	4.35**	3.60	5.25	5.19**	4.13	6.53

Marital Status									
single	*reference*			*reference*			*reference*		
married/common law	0.80**	0.68	0.94	0.72**	0.60	0.86	0.50**	0.39	0.65
Employment									
employed	*reference*			*reference*			*reference*		
student	0.77**	0.69	0.87	0.70**	0.61	0.80	0.72**	0.59	0.88
unemployed	0.72**	0.57	0.90	0.62**	0.48	0.81	0.61**	0.43	0.87
other	0.54**	0.44	0.65	0.44**	0.35	0.56	0.40**	0.28	0.56
Sex									
female	*reference*			*reference*			*reference*		
male	0.99	0.90	1.09	1.09	0.98	1.23	1.72**	1.45	2.04
Education									
less than high-school	*reference*			*reference*			*reference*		
high-school diploma	2.52**	2.19	2.90	3.44**	2.88	4.11	2.95**	2.26	3.85
post-secondary	2.92**	2.45	3.49	4.67**	3.78	5.78	4.11**	3.05	5.54
Race									
white	*reference*			*reference*			*reference*		
non-white	0.52**	0.46	0.59	0.51**	0.44	0.58	0.43**	0.34	0.53
Immigrant									
no	*reference*			*reference*			*reference*		
yes	0.46**	0.40	0.53	0.36**	0.30	0.43	0.22**	0.16	0.31
Household Income									
decile 1	*reference*			*reference*			*reference*		
decile 2	1.10	0.89	1.36	1.10	0.86	1.40	1.16	0.83	1.63
decile 3	1.21	0.98	1.50	1.01	0.79	1.31	1.21	0.85	1.72
decile 4	1.02	0.82	1.26	0.98	0.77	1.26	1.02	0.71	1.46
decile 5	1.13	0.91	1.40	0.99	0.77	1.27	1.10	0.76	1.59
decile 6	0.96	0.77	1.19	0.92	0.71	1.18	1.19	0.83	1.70
decile 7	1.21	0.98	1.51	1.20	0.93	1.54	1.09	0.75	1.59
decile 8	1.33**	1.07	1.64	1.09	0.85	1.41	1.09	0.75	1.59
decile 9	1.38**	1.11	1.70	1.11	0.86	1.43	1.26	0.87	1.82

decile 10	1.24*	1.00	1.54	1.55*	1.21	1.99	1.87**	1.31	2.66
Self Perceived Stress									
extremely stressed	*reference*			*reference*			*reference*		
quite a bit stressed	1.76**	1.23	2.53	1.59*	1.06	2.39	1.49	0.87	2.54
a bit stressed	1.43*	1.01	2.04	1.19	0.80	1.77	1.07	0.64	1.81
not very stressed	1.27	0.89	1.82	1.01	0.67	1.52	0.93	0.55	1.60
not at all stressed	1.03	0.70	1.52	0.85	0.55	1.33	0.94	0.52	1.69
Self Perceived Health									
poor	*reference*			*reference*			*reference*		
fair	2.69**	1.33	5.43	1.94*	0.89	4.23	3.08*	1.04	9.08
good	3.06**	1.55	6.04	2.22*	1.05	4.68	2.71	0.94	7.80
very Good	3.59**	1.82	7.08	2.83**	1.34	5.98	3.71*	1.29	10.69
excellent	3.31**	1.67	6.57	2.77**	1.30	5.89	3.26*	1.12	9.48
Sexual Orientation									
heterosexual	*reference*			*reference*			*reference*		
homosexual	1.17	0.86	1.59	0.93	0.64	1.34	0.95	0.59	1.55
bisexual	1.16	0.94	1.44	0.88	0.67	1.15	1.31	0.93	1.85
Anxiety Disorder									
no	*reference*			*reference*			*reference*		
yes	0.95	0.81	1.13	0.89	0.73	1.09	1.14	0.88	1.49
Mood Disorder									
no	*reference*			*reference*			*reference*		
yes	1.15	0.94	1.39	1.03	0.82	1.29	0.95	0.71	1.28

[1]reference category for outcome = 'Never'

[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Model 2B explored the overall association between past-year binge drinking and residential greenness through binary logistic regression. This model collapsed active categories of binge drinking and compared the odds of being a past-year binge drinker, versus non-binge drinker, across greenness quartiles. Like model 2A, there was no statistically significant difference between the greenest versus least green quartile. Results for the second greenest quartile, however, were on the cusp of statistical significance and indicated an 11% (OR .89; 95% C.I .79, 1.00) decrease in the odds of binge drinking compared to those in quartile one.

Other covariates that were significantly related to past-year binge drinking include: urbanicity, BMI, age, smoking, marijuana use, marital status, employment status, education, race, immigration status, and self-perceived health.

Table 7: Model 2(B) Residential Greenness and Binge Drinking (Yes/No)

Characteristic	**Odds Ratio**	**95% C.I.**	
Residential Greenness			
Quartile 1	*reference*		
Quartile 2	0.90	0.80	1.02
Quartile 3	0.89	0.79	1.00
Quartile 4	1.00	0.88	1.13
Urban			
small	*reference*		
medium	0.72**	0.63	0.83
large	0.73**	0.65	0.81
BMI			
underweight	*reference*		
normal	1.54**	1.31	1.81
overweight	1.62**	1.35	1.94
obese	1.32**	1.08	1.62
Age			
15-18	*reference*		
19-21	2.17**	1.88	2.49
22-25	2.15**	1.84	2.50

Smoker			
no	*reference*		
yes	4.38**	3.79	5.06
Marijuana user			
no	*reference*		
yes	3.46**	2.93	4.08
Marital Status			
single	*reference*		
married/common law	0.74**	0.64	0.85
Employment			
employed	*reference*		
student	0.74**	0.67	0.83
unemployed	0.67**	0.55	0.83
other	0.49**	0.41	0.58
Sex			
female	*reference*		
male	1.07	0.98	1.17
Education			
less than high-school	*reference*		
high-school diploma	2.78**	2.45	3.16
post-secondary	3.45**	2.94	4.05
Race			
white	*reference*		
non-white	0.51**	0.46	0.56
Immigrant			
no	*reference*		
yes	0.40**	0.35	0.46
Household Income			
decile 1	*reference*		
decile 2	1.11	0.92	1.34
decile 3	1.15	0.95	1.40
decile 4	1.01	0.83	1.23
decile 5	1.09	0.90	1.32
decile 6	0.97	0.80	1.18
decile 7	1.21	0.99	1.46
decile 8	1.24**	1.02	1.51
decile 9	1.29**	1.07	1.57
decile 10	1.39**	1.14	1.69
Self Perceived Stress			
extremely stressed	*reference*		
quite a bit stressed	1.67**	1.21	2.29
a bit stressed	1.31	0.96	1.79

not very stressed	1.14	0.83	1.57
not at all stressed	0.96	0.68	1.34
Self Perceived Health			
poor	*reference*		
fair	2.46**	1.36	4.47
good	2.73**	1.54	4.85
very Good	3.33**	1.87	5.92
excellent	3.12**	1.75	5.57
Sexual Orientation			
heterosexual	*reference*		
homosexual	1.08	0.81	1.43
bisexual	1.09	0.89	1.33
Anxiety Disorder			
no	*reference*		
yes	0.95	0.81	1.11
Mood Disorder			
no	*reference*		
yes	1.09	0.91	1.30

[1]reference category for outcome = 'Never'
[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

4.3.3 Past Year Tobacco Use

Model 3A explored past year tobacco use at different levels of residential greenness using multinomial regression. In the adjusted model, those in the greenest quartile had lower odds of being a low use smoker, vs. non-smoker, compared to the least green quartile (OR .80; 95% C.I. .68, .95). Results were similar for the second greenest quartile, where greenness was associated with a 21% decrease in the odds of being a low-use smoker, vs non-smoker, compared to those in the least green quartile (OR .79; 95% C.I .68, .93). Results for moderate and heavy smokers were not statistically significant.

Marijuana use and alcohol use were significantly associated with all levels of tobacco use. For low use smokers, marijuana use was associated with an approximately two-fold increase in the odds smoking (OR 2.24; 95% C.I 1.94, 2.59), and alcohol use was associated with an

approximately four-fold increase in the odds of smoking (OR 4.64; 95% C.I 3.67, 5.86). Males were also consistently more likely than females to be in any category of smoking. Among low use smokers, men had a 50% increase in the odds of smoking (OR .1.5; 95% C.I 1.33, 1.69). Other covariates that were significantly associated with tobacco use were: being from a large urban area, age, employment status, education, household income, having a mood disorder, having an anxiety disorder.

Table 8: Model 3(A) Residential Greenness and Tobacco Frequency

Characteristic	**Low (1-10 Cigarettes)**			**Moderate (11-19 Cigarettes)**			**High (20+ Cigarettes)**		
	Odds Ratio	95% C.I.		Odds Ratio	95% C.I.		Odds Ratio	95% C.I.	
Residential Greenness									
Quartile 1	*reference*			*reference*			*reference*		
Quartile 2	0.95	0.81	1.10	1.01	0.71	1.43	1.14	0.76	1.74
Quartile 3	0.79**	0.68	0.93	0.86	0.60	1.22	1.09	0.72	1.64
Quartile 4	0.80*	0.68	0.95	1.22	0.86	1.73	0.90	0.57	1.42
Urban									
small	*reference*			*reference*			*reference*		
medium	0.90	0.75	1.07	0.75	0.53	1.06	0.65*	0.43	0.98
large	0.79**	0.69	0.91	0.51**	0.38	0.69	0.35**	0.25	0.51
BMI									
underweight	*reference*			*reference*			*reference*		
normal	1.06	0.84	1.34	1.39	0.78	2.46	0.96	0.51	1.81
overweight	0.98	0.76	1.27	1.45	0.79	2.67	0.93	0.47	1.83
obese	0.85	0.64	1.13	0.97	0.51	1.84	0.85	0.42	1.72
Age									
15-18	*reference*			*reference*			*reference*		
19-21	2.31**	1.89	2.82	3.09**	1.95	4.89	4.63**	2.50	8.58
22-25	2.45**	1.98	3.02	4.60**	2.90	7.30	7.86**	4.25	14.55
Marijuana User									
no	*reference*			*reference*			*reference*		
yes	2.24**	1.94	2.59	1.99*	1.46	2.72	1.66*	1.12	2.46
Past Year Alcohol Use									
no	*reference*			*reference*			*reference*		
yes	4.64**	3.67	5.86	2.15**	1.37	3.36	2.75**	1.50	5.04
Marital Status									
single	*reference*			*reference*			*reference*		
married/common law	0.99	0.83	1.17	1.51*	1.11	2.08	1.40	0.96	2.05
Employment									

employed	*reference*			*reference*			*reference*		
student	0.69**	0.60	0.80	0.31**	0.21	0.46	0.26**	0.15	0.43
unemployed	1.28*	1.02	1.61	0.99	0.62	1.57	1.00	0.59	1.68
other	1.04	0.83	1.29	1.01	0.69	1.50	1.00	0.64	1.58
Sex									
female	*reference*			*reference*			*reference*		
male	1.50**	1.33	1.69	2.05**	1.57	2.68	3.37**	2.39	4.75
Education									
less than high-school	*reference*			*reference*			*reference*		
high-school diploma	0.71**	0.59	0.85	0.34**	0.24	0.47	0.24**	0.17	0.36
post-secondary	0.45**	0.36	0.55	0.17**	0.11	0.25	0.14**	0.09	0.22
Race									
white	*reference*			*reference*			*reference*		
non-white	1.13	0.98	1.30	0.81	0.58	1.12	1.06	0.73	1.54
Immigrant									
no	*reference*			*reference*			*reference*		
yes	0.96	0.80	1.15	0.34**	0.17	0.66	0.64	0.34	1.20
Household Income									
decile 1	*reference*			*reference*			*reference*		
decile 2	0.94	0.75	1.17	0.87	0.57	1.34	0.85	0.52	1.39
decile 3	0.82	0.65	1.03	0.69	0.43	1.09	.42**	0.23	0.77
decile 4	0.77*	0.61	0.97	0.62	0.38	1.00	0.66	0.39	1.14
decile 5	0.63**	0.49	0.80	0.32**	0.18	0.58	0.33**	0.17	0.63
decile 6	0.57**	0.45	0.73	0.48**	0.29	0.82	.028**	0.19	0.72
decile 7	0.54**	0.42	0.69	0.39**	0.22	0.70	0.56	0.30	1.04
decile 8	0.51**	0.39	0.66	0.45**	0.26	0.79	0.16**	0.06	0.43
decile 9	0.50**	0.39	0.65	0.47**	0.27	0.83	0.22**	0.09	0.53
decile 10	0.53**	0.41	0.68	0.28**	0.14	0.56	0.42*	0.21	0.87
Self Perceived Stress									
extremely stressed	*reference*			*reference*			*reference*		
quite a bit stressed	0.72	0.50	1.05	0.83	0.42	1.65	0.90	0.43	1.88

a bit stressed	0.70	0.49	1.01	0.67	0.34	1.30	0.45	0.21	0.93
not very stressed	0.63*	0.43	0.92	0.50	0.24	1.01	0.47	0.22	1.02
not at all stressed	0.76	0.50	1.15	0.51	0.22	1.19	0.29*	0.11	0.81
Self Perceived Health									
poor	*reference*			*reference*			*reference*		
fair	1.47	0.75	2.88	0.62	0.23	1.68	1.77	0.47	6.66
good	1.15	0.60	2.21	0.81	0.32	2.05	1.08	0.29	3.99
very Good	0.84	0.44	1.63	0.45	0.17	1.16	0.44	0.12	1.67
excellent	0.63	0.33	1.23	0.17**	0.06	0.47	0.29	0.07	1.14
Sexual Orientation									
heterosexual	*reference*			*reference*			*reference*		
homosexual	1.10	0.79	1.53	0.95	0.46	1.95	0.96	0.43	2.18
bisexual	1.31	1.04	1.64	1.95**	1.29	2.95	0.59	0.28	1.27
Mood Disorder									
no	*reference*			*reference*			*reference*		
yes	1.43**	1.18	1.73	1.43	0.99	2.07	1.44	0.93	2.23
Anxiety Disorder									
no	*reference*			*reference*			*reference*		
yes	1.37**	1.15	1.64	1.61**	1.14	2.27	1.64*	1.08	2.48

[1]reference category for outcome = 'Never'

[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Model 3B explored the overall association between past-year smoking and residential greenness through binary logistic regression. This model collapsed active categories of cigarette use and compared the odds of being a past-year smoker, versus non-smoker, across greenness quartiles. Those in the greenest quartile had a 15% decrease in the odds of being a smoker, vs non-smoker, compared to the least green quartile (OR .85; 95% C.I .73, .99). Results were similar in the second greenest quartile, where greenness was associated with a 18% decrease in the odds of being a smoker, vs non-smoker, compared to the least green quartile (OR .82; 95% C.I .71, .95).

Other Covariates that were significantly related to past year smoking include: urbanicity, age, marijuana use, alcohol use, being a student, sex, educational attainment, household income, self-perceived stress, bisexual orientation, mood disorder, and anxiety disorder.

Table 9: Model 3(B) Residential Greenness and Tobacco Use (Yes/No)

Characteristic	**Odds Ratio**	**95% C.I.**	
Residential Greenness			
Quartile 1	*reference*		
Quartile 2	0.96	0.83	1.11
Quartile 3	0.82**	0.71	0.95
Quartile 4	0.85*	0.73	0.99
Urban			
small	*reference*		
medium	0.85*	0.72	0.99
large	0.70**	0.62	0.80
BMI			
underweight	*reference*		
normal	1.10	0.88	1.37
overweight	1.04	0.82	1.32
obese	0.86	0.67	1.12
Age			
15-18	*reference*		
19-21	2.70**	2.24	3.25
22-25	3.09**	2.55	3.75

Marijuana User			
no	*reference*		
yes	2.16**	1.88	2.48
Past Year Alcohol Use			
no	*reference*		
yes	4.01**	3.27	4.90
Marital Status			
single	*reference*		
married/common law	1.09	0.93	1.27
Employment			
employed	*reference*		
student	0.60**	0.52	0.68
unemployed	1.22	0.99	1.51
other	1.06	0.87	1.29
Sex			
female	*reference*		
male	1.65**	1.48	1.84
Education			
less than high-school	*reference*		
high-school diploma	0.56**	0.48	0.67
post-secondary	0.33*	0.28	0.40
Race			
white	*reference*		
non-white	1.09	0.95	1.24
Immigrant			
no	*reference*		
yes	0.87	0.73	1.04
Household Income			
decile 1	*reference*		
decile 2	0.91	0.75	1.12
decile 3	0.75**	0.61	0.93
decile 4	0.73**	0.59	0.91
decile 5	0.55**	0.44	0.69
decile 6	0.54**	0.43	0.68
decile 7	0.51**	0.40	0.65
decile 8	0.46**	0.37	0.59
decile 9	0.48**	0.38	0.61
decile 10	0.48**	0.38	0.61
Self Perceived Stress			
extremely stressed	*reference*		
quite a bit stressed	0.73	0.52	1.03
a bit stressed	0.66*	0.47	0.92
not very stressed	0.59**	0.42	0.83

not at all stressed	0.68*	0.46	0.99
Self Perceived Health			
poor	*reference*		
fair	1.27	0.70	2.28
good	1.03	0.58	1.82
very Good	0.69	0.39	1.23
excellent	0.48*	0.27	0.86
Sexual Orientation			
heterosexual	*reference*		
homosexual	1.07	0.79	1.45
bisexual	1.32*	1.07	1.63
Anxiety Disorder			
no	*reference*		
yes	1.42**	1.19	1.70
Mood Disorder			
no	*reference*		
yes	1.43**	1.21	1.68

[1]reference category for outcome = 'Never'
[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

4.3.4 Past Year Marijuana Use

Model 4A explored past year marijuana/hash frequency at different levels of residential greenness using multinomial regression. In the adjusted model, there was no statistically significant differences between past year marijuana/hash frequency and residential greenness in the greenest versus least green quartile. In the second and third greenest quartiles, however, results were significant. In the second greenest quartile, individuals had increased odds of being in any category of marijuana use, vs non-use. These individuals had an 81% increase in the odds of being a weekly user (OR 1.81; 95% C.I 1.31, 2.51) and a nearly 50% increase in the odds of being a daily user (OR 1.49; 95% C.I 1.01, 2.20). In the third greenest quartile, individuals had increased odds of being rare or weekly marijuana users, vs non-users. These individuals had a

28% increase in the odds of being a rare user (OR 1.28; 95% C.I 1.03, 1.60) and a 43% increase in the odds of being a weekly user (OR 1.43; 95% C.I 1.02, 2.00).

Past year alcohol use and smoking were significantly associated with all levels of marijuana use. Holding all other covariates constant, smoking was associated with a nearly four-fold increase in the odds of daily, versus never, marijuana use (OR 3.87; 95% C.I 2.82, 5.30), and past year alcohol use was associated with an approximately six-fold increase in the odds of daily, versus never, marijuana use (OR 6.21; 95% C.I 2.49, 15.46). Sex was associated with often and daily, versus never, marijuana use. Men had an 82% increase in the odds of daily, versus never, marijuana use (OR 1.82; 95% C.I 1.33, 2.51).

Other covariates that were significantly related to marijuana use include: urbanicity, BMI, age, marital status, educational attainment, employment status, immigration status, self-perceived health, sexual orientation, mood disorder, anxiety disorder.

Table 10: Model 4(A) Residential Greenness and Marijuana Frequency

Characteristic	**Sometimes (<3 times/month)**			**Often (1-6 times/week)**			**Daily**		
	Odds Ratio	95% C.I.		Odds Ratio	95% C.I.		Odds Ratio	95% C.I.	
Residential Greenness									
Quartile 1	*reference*			*reference*			*reference*		
Quartile 2	1.28*	1.03	1.60	1.43*	1.02	2.00	1.08	0.72	1.63
Quartile 3	1.64**	1.33	2.02	1.81**	1.31	2.51	1.49*	1.01	2.20
Quartile 4	1.20	0.95	1.52	1.02	0.69	1.52	0.94	0.60	1.49
Urban									
small	*reference*			*reference*			*reference*		
medium	1.48*	1.18	1.87	1.35	0.92	1.98	1.94**	1.31	2.88
large	1.13	0.93	1.37	1.23	0.90	1.68	0.88	0.61	1.28
BMI									
underweight	*reference*			*reference*			*reference*		
normal	1.03	0.75	1.42	1.25	0.73	2.12	0.63	0.39	1.02
overweight	1.08	0.76	1.54	0.82	0.45	1.48	0.37**	0.21	0.66
obese	0.91	0.62	1.34	0.80	0.42	1.52	0.24**	0.12	0.47
Age									
15-18	*reference*			*reference*			*reference*		
19-21	1.14	0.88	1.46	1.04	0.68	1.58	2.37**	1.39	4.01
22-25	1.14	0.87	1.49	1.48	0.97	2.26	2.16**	1.24	3.76
Smoker									
no	*reference*			*reference*			*reference*		
yes	1.55**	1.29	1.87	3.43**	2.64	4.45	3.87**	2.82	5.30
Past Year Alcohol User									
no	*reference*			*reference*			*reference*		
yes	7.62**	5.04	11.52	2.95**	1.76	4.96	6.21**	2.49	15.46
Marital Status									
single	*reference*			*reference*			*reference*		
married/common law	0.63**	0.48	0.83	0.71	0.48	1.04	0.90	0.59	1.38
Employment									

employed	*reference*			*reference*			*reference*		
student	0.87	0.72	1.05	0.78	0.58	1.07	.64*	0.42	0.97
unemployed	1.23	0.90	1.69	0.95	0.58	1.56	1.17	0.71	1.93
other	0.81	0.58	1.13	0.68	0.41	1.12	0.83	0.50	1.38
Sex									
female	*reference*			*reference*			*reference*		
male	1.05	0.89	1.23	1.66**	1.28	2.15	1.82**	1.33	2.51
Education									
less than high-school	*reference*			*reference*			*reference*		
high-school diploma	1.35*	1.06	1.72	1.63*	1.12	2.38	1.13	0.74	1.70
post-secondary	1.26	0.94	1.67	1.19	0.76	1.85	0.84	0.51	1.37
Race									
white	*reference*			*reference*			*reference*		
non-white	1.10	0.91	1.34	1.23	0.92	1.66	1.26	0.89	1.79
Immigrant									
no	*reference*			*reference*			*reference*		
yes	0.74*	0.56	0.97	0.56*	0.36	0.87	0.30**	0.15	0.62
Household Income									
decile 1	*reference*			*reference*			*reference*		
decile 2	0.87	0.61	1.24	1.22	0.78	1.91	0.86	0.50	1.48
decile 3	0.96	0.67	1.37	0.92	0.55	1.52	1.14	0.66	1.97
decile 4	1.04	0.73	1.48	0.72	0.42	1.24	0.96	0.54	1.72
decile 5	1.00	0.70	1.44	1.02	0.61	1.70	0.99	0.54	1.82
decile 6	1.32	0.94	1.85	0.86	0.50	1.46	0.61	0.31	1.22
decile 7	1.09	0.76	1.55	0.68	0.38	1.21	0.74	0.38	1.46
decile 8	1.26	0.90	1.78	0.78	0.45	1.37	0.93	0.48	1.78
decile 9	1.23	0.87	1.73	0.49	0.26	0.92	0.57	0.28	1.19
decile 10	1.38	0.99	1.94	1.18	0.71	1.96	0.71	0.35	1.45
Self perceived Stress									
extremely stressed	*reference*			*reference*			*reference*		
quite a bit stressed	1.78	0.91	3.48	1.17	0.56	2.45	0.97	0.46	2.07

a bit stressed	1.96*	1.02	3.80	1.03	0.50	2.13	0.75	0.36	1.56
not very stressed	1.90	0.97	3.72	1.02	0.48	2.18	0.95	0.43	2.07
not at all stressed	1.16	0.56	2.43	0.65	0.26	1.60	0.98	0.39	2.46
Self Perceived Health									
poor	*reference*			*reference*			*reference*		
fair	0.98	0.36	2.65	0.44	0.16	1.22	0.97	0.30	3.12
good	0.78	0.30	2.05	0.41	0.16	1.05	0.61	0.19	1.91
very Good	0.77	0.29	2.03	0.42	0.16	1.10	0.39	0.12	1.26
excellent	0.79	0.30	2.10	0.35*	0.13	0.94	0.26*	0.08	0.90
Sexual Orientation									
heterosexual	*reference*			*reference*			*reference*		
homosexual	1.18	0.76	1.83	1.45	0.79	2.63	0.83	0.35	1.97
bisexual	1.27	0.93	1.73	1.59*	1.03	2.47	1.65*	1.01	2.68
Anxiety Disorder									
no	*reference*			*reference*			*reference*		
yes	0.91	0.70	1.17	1.45*	1.01	2.07	1.12	0.74	1.70
Mood Disorder									
no	*reference*			*reference*			*reference*		
yes	1.79**	1.38	2.33	1.42	0.97	2.09	2.24**	1.48	3.39

[1]reference category for outcome = 'Never'

[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Model 4B explored the overall association between past-year marijuana/hash use and residential greenness through binary logistic regression. This model collapsed active categories of marijuana/hash use and compared the odds of being a past-year marijuana/hash user, vs non-user, in the greenest versus least green quartile. There was no statistically significant difference between the greenest vs least green quartile. Results for the second and third greenest quartiles, however, were statistically significant. Individuals in the second greenest quartile had a 67% increase in the odds of past year marijuana use, compared to the least green quartile (OR 1.67; 95% C.I 1.42, 1.96), and individuals in the third greenest quartile had a 26% increase in the odds of past year marijuana/hash use, compared to the least green quartile (OR 1.26; 95% C.I 1.06, 1.49).

Other covariates significantly associated with past year marijuana use include: urbanicity, smoking, alcohol use, marital status, employment status, sex, immigration, self-perceived health, bisexual orientation, and mood disorder.

Table 11: Model 4(B) Residential Greenness and Marijuana Use (Yes/No)

Characteristic	**Odds Ratio**	**95% C.I.**	
Residential Greenness			
Quartile 1	*reference*		
Quartile 2	1.26**	1.06	1.49
Quartile 3	1.67**	1.42	1.96
Quartile 4	1.07	0.90	1.29
Urban			
small	*reference*		
medium	1.56**	1.30	1.86
large	1.15	0.99	1.33
BMI			

underweight	*reference*		
normal	1.07	0.84	1.36
overweight	0.93	0.71	1.22
obese	0.77	0.57	1.03
Age			
15-18	*reference*		
19-21	1.12	0.92	1.36
22-25	1.12	0.91	1.38
Smoker			
no	*reference*		
yes	2.10**	1.83	2.40
Past Year Alcohol User			
no	*reference*		
yes	5.70**	4.32	7.51
Marital Status			
single	*reference*		
married/common law	0.71**	0.58	0.87
Employment			
employed	*reference*		
student	0.82**	0.71	0.95
unemployed	1.11	0.87	1.42
other	0.77*	0.60	0.99
Sex			
female	*reference*		
male	1.27**	1.13	1.44
Education			
less than high-school	*reference*		
high-school diploma	1.24*	1.04	1.49
post-secondary	1.06	0.85	1.31
Race			
white	*reference*		
non-white	1.15	1.00	1.34
Immigrant			
no	*reference*		
yes	0.63**	0.51	0.78
Household Income			
decile 1	*reference*		
decile 2	0.99	0.77	1.28
decile 3	1.06	0.82	1.38
decile 4	0.91	0.70	1.19
decile 5	1.09	0.84	1.42
decile 6	1.07	0.82	1.39
decile 7	0.90	0.69	1.19

decile 8	1.18	0.91	1.53
decile 9	0.98	0.75	1.29
decile 10	1.19	0.92	1.55
Self Perceived Stress			
extremely stressed	*reference*		
quite a bit stressed	1.26	0.83	1.90
a bit stressed	1.24	0.82	1.86
not very stressed	1.24	0.81	1.88
not at all stressed	0.93	0.58	1.49
Self Perceived Health			
poor	*reference*		
fair	0.65	0.34	1.22
good	0.53*	0.29	0.99
very Good	0.50*	0.27	0.93
excellent	0.45*	0.24	0.84
Sexual Orientation			
heterosexual	*reference*		
homosexual	1.19	0.85	1.66
bisexual	1.38**	1.10	1.74
Mood Disorder			
no	*reference*		
yes	1.74**	1.42	2.12
Anxiety Disorder			
no	*reference*		
yes	1.06	0.88	1.28

[1]reference category for outcome = 'Never'

[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

CHAPTER 5: DISCUSSION AND CONCLUSIONS

5 Introduction

This chapter discusses the findings from Chapter 4 and contextualizes them within the wider literature discussed in Chapter 2. The chapter also highlights strengths and limitations of the study and addresses policy implications and considerations for future research.

5.1 Substance Use Prevalence

The prevalence of substance use among transitional aged youth mirrored estimates from other Canadian studies (Government of Canada, 2019; Leatherdale & Ahmed, 2010; Leatherdale & Burkhalter, 2011). One exception, however, was that past year marijuana use had a lower prevalence than other Canadian studies. Past year alcohol use had the highest prevalence (74%), followed by binge drinking (53%), tobacco use (16%), and marijuana use (11%). Polysubstance use, additionally, was very high, with most substance users indicating use of more than one substance. This finding is also mirrored in other Canadian research that found a high prevalence of polysubstance use, especially among adolescents (Zuckermann *et al*., 2018). This study found that the most common pattern of polysubstance use involved binge drinking and smoking, with 25% of binge drinkers being smokers, compared to 6% of non-binge drinkers, and 82% of smokers reporting binge drinking, compared to 47% of non-smokers. This finding corroborates other research that has also noted strong correlations between smoking and binge drinking behaviours (Johnston *et al*., 2000; Weitzman & Chen, 2005).

5.2 Residential Greenness and Substance Use

In terms of the association between residential greenness and substance use, it should be restated that this was an exploratory analysis and that the results remain limited. This, however, should not detract from the overall value and contribution that this research makes to the wider literature. This was the first study to explore the association between residential greenness and alcohol, marijuana, and tobacco use. Only three other studies have explored dimensions of greenness and substance use, i.e., substance abuse disorders and interactive effects of greenness on substance use, but neither explored variation in the patterns of substance use through intensity and frequency measures (Engemann 2019; Mennis, 2021). This thesis, therefore, provides a framework from which future research can expand.

5.2.1 Residential Greenness and Alcohol Use

When investigating the frequency of past year alcohol use, there was no statistically significant associations with increasing levels of greenness. Given the broad societal acceptance of alcohol use, these results are not surprising. It was expected that low levels of alcohol use would remain relatively constant across greenness quartiles after control of suspected confounders. It was the relationship between greenness and high levels of drinking (e.g., weekly drinking) that was the primary interest of this model. The model, however, was not able to detect any statistically significant findings for this category of drinking. It is important to note, however, that this model was only able to capture a portion of alcohol use information – drinking frequency. To understand patterns of alcohol use more fully, drinking intensity must also be considered. Various research has documented that alcohol frequency and intensity are not interchangeable,

and the control of one in contrast to the other, can lead to different conclusions (Heckley *et al*., 2017).

To more fully investigate both dimensions of alcohol use, a second set of models explored variation between residential greenness and binge drinking. Unlike the former analysis, this outcome involved both frequency and intensity measures. Like the frequency models, no statistically significant results were noted for the greenest versus the least green areas, but the direction of the point-estimates more closely aligned with the initial hypothesis. In the other greenness quartiles (quartile two and quartile three), the odds of binge drinking were significantly lower compared to the least green quartile. In quartile two, residential greenness was associated with a reduction in the odds of being a monthly vs. never, and weekly vs. never binge drinker, compared to those in the least green quartile. Additionally, in quartile three, residential greenness was associated with a reduction in the odds of being a monthly vs. never binge drinker, compared to those in the least green quartile. While any amount of binge drinking is considered risky behaviour, these results suggest that increased levels of residential greenness are more strongly associated with the extreme categories of binge drinking behaviour (monthly and weekly), and less with rare or infrequent (less than monthly) bouts of binge drinking. This hypothesis aligns with the results of Engemann *et al.* (2019), and suggests that the association between greenness and alcohol use might be defined by *substance abusive* tendencies. Engemann *et al.* (2019), for example, explored greenness associations with substance use disorders and found that individuals in the least green areas had a 40% increase in the risk of developing an alcohol abuse disorder. Future research should explore both clinical and sub-clinical thresholds of alcohol abuse to further substantiate potential protective mechanisms.

5.2.2 Residential Greenness and Tobacco Use

An inverse relationship was found between current tobacco use and residential greenness that persisted after control of suspected confounders. Those in the greenest two quartiles had lower odds of being a current smoker compared to those in the least green quartile. When considering smoking intensity, the association was strengthened, with those in the greenest two quartiles having lower odds of being a low-use (1-10 cigarettes per day) smoker compared to those in the least green quartile.

These results closely parallel those from Martin *et al*. (2020) and add additional context to their discussion on the protective effects of green space. Martin *et al*. (2020) noted a reduction in the prevalence of current smokers in the greenest areas, as well as a higher prevalence of former smokers in the greenest vs. least green areas. When considering both results together (i.e., a higher relative prevalence of former smokers and a lower relative prevalence of current smokers), they hypothesised that the association between green space and smoking may be more strongly influenced by smoking cessation than by smoking initiation. Considering the broad age range of their sample (ages 16-65+ years), and the fact that smoking initiation tends to start young, their hypothesis seems reasonable. Conversely, the current study investigated smoking amongst an age group noted for experimentation and initiation into substance use (*Griffin et al*., 2021). The likelihood then of former but not current cigarette use is much less likely relative to older cohorts. If this holds true, then residential greenness may be directly implicated in the etiology of cigarette initiation amongst young individuals. While this is in the realm of conjecture, it suggests that residential greenness may be implicated in dual pathways of protection, one linked to smoking initiation and another smoking cessation. Uncovering causal mechanisms that underlie each pathway is a task for future research.

5.2.3 Residential Greenness and Marijuana Use

The most surprising results of this study pertain to the association between residential greenness and marijuana use. Individuals in the second greenest quartile had a nearly 70% increase in the odds of past year marijuana use compared to those in the least green quartile. In terms of marijuana use frequency, individuals in the second greenest quartile had a nearly 50% increase in the odds of being a daily user vs. non-user, and an 80% increase in the odds of being a weekly user vs. non-user, compared to those in the least green quartile. Results were more attenuated when comparing the third greenest areas to the least green areas but the odds of being in any category of use remained elevated (i.e., odds ratios greater than one). Given the pattern of association between binge drinking and greenness, and tobacco use and greenness, these results are perplexing. Marijuana use, for example, co-occurred with both binge drinking and tobacco use at a high rate. Similarly, the prevalence of *marijuana only* users was low (.3%), suggesting that marijuana use does not tend to occur independent to other substances. A possible explanation for this discrepancy might have to do with urbanicity and other related constructs. In the alcohol and tobacco models, living in medium and large urban areas was associated with a decrease in the odds of substance use. In the marijuana models, however, medium urban areas were associated with an increase in substance use. Perhaps then, certain characteristics of larger urban areas, like availability or retail density, are important to patterns of use. Another possible explanation for these results is misclassification of marijuana use. The prevalence of past year marijuana use was relatively low (11%) compared to other studies. A 2017 study, for example, found that past year marijuana prevalence was 19% for Canadian youth, aged 15-19, and 33% for young adults, aged 20-24 (Government of Canada, 2017). Whether or not this

misclassification varies by residential greenness is beyond the scope of this thesis, but it should be considered when interpreting these results.

5.3 Policy Implications

Similar to other green space and health research, this study found that higher levels of residential greenness was associated with reductions for certain categories of substance use. Given the scope of substance use and abuse in Canada this finding could have broad policy implications. First, these findings speak to the importance of protecting urban green spaces and ensuring adequate proximity to spaces like urban parks and gardens. Ensuring sufficient access and proximity to green spaces represents an easy and minimally invasive strategy to potentially curb substance abusive behaviours. With a large 'at risk' population of substance users, such an approach stands to benefit a significant proportion of individuals in various health-related ways. Secondly, these findings speak to the potential for governments and/or private enterprise to utilize green spaces as a more central component for the delivery of addiction services. Finding therapeutic ways to engage individuals within green spaces might further contribute to clinical outcomes. Smoking cessation programs, for example, provide an interesting context for such an intervention given the strong, relative associations, between both prevalence and cessation with residential greenness (Martin *et al*., 2020).

5.4 Strengths & Limitations

This study was the first to evaluate the association between residential greenness and multiple forms of substance use. Very few green space studies have considered substance use outcomes, and those that have, tended to focus on narrow at-risk populations, defined by substance *abuse*. By focusing on substance *use*, results from the current study are more generalizable. Secondly,

by limiting the sample to an age group noted for experimentation and initiation into substance use, the confounding influence of former substance use, and the related processes therein, are greatly reduced. Third, unlike other studies, the current study chose an NDVI buffer less amenable to misclassification. Much of the literature has favored a 500m buffer, often citing 'comparability with other studies' as the primary motivation for selection. Few authors, however, have explicitly considered exposure misclassification with buffers of this size.

While there are many strengths to the current study, there are also several limitations. First, while the CCHS is a nationally representative survey, measures of substance use are based solely on self-report. Given the sensitive nature of this topic, in conjunction with the young age range of participants, many outcomes were likely under-reported. Similarly, since the study period covered a timeframe when marijuana was still illegal, there might have been additional pressure for some users to report no use at all, thus resulting in some misclassification. Second, using survey data, the study followed a cross-sectional design limiting the ability for causal inference. While measures of substance use and residential greenness were temporally bound to the previous 12 months, individuals may have moved or spent little time at their principal address during the study period. Third, measures of greenness were limited to NDVI estimates. While the use of NDVI is a common approach, without additional greenness measures (e.g., proximity or engagement measures) it is difficult to assess the mechanisms and pathways through which greenness is involved. Fourth, this study was not able to differentiate between never and former substance users. This distinction has important implications for understanding potential benefits/risks for different populations. However, given the young age of the sample, the prevalence of former users is likely relatively low across outcomes. Fifth, while this study was able to control for a host of theoretically important covariates, it was not able to control for

several personality and behavioural characteristics (e.g., risk-taking, deviancy, peer-group association) or neighbourhood-level characteristics (e.g., neighbourhood income, deprivation scores), thus contributing to residual confounding. Sixth, this study did not provide results by important subgroups. Analyses based on sex, mental health status, and ethnicity, may provide additional insights into the relationship between green space and substance use but were beyond the scope of this thesis. Seventh, given the sampling strategy of the CCHS results only remain generalizable to the sample.

5.5 Future Research

Future research should continue to investigate the relationship between green space and substance use by looking at both substance use patterns and substance use disorders. Currently, two studies have explored residential greenness and substance use disorders, and two, including this one, have explored residential greenness and substance use patterns. Given the scant amount of research on this topic, it is still unclear if residential greenness is important to both outcomes, but the results this far seem promising.

Additionally, given the exploratory nature of this work, future research should focus on a strong methodology rooted in multiple exposure and outcome (i.e., frequency and intensity) measures, and postpone discussions involving causal mechanisms until a more solid evidentiary base has been established. Given the high prevalence of polysubstance use, especially alcohol, tobacco, and marijuana, future research should continue to simultaneously explore all three outcomes. Other potential outcomes, with significant public health implications, that would be interesting to explore are vaping and opiate use.

5.6 Conclusions

Given the limited amount of research involving greenness and substance use, this study undertook an exploratory analysis of potential associations with three of the most used substances – alcohol, tobacco, and marijuana, among transitional aged youth. In line with other research that has noted protective associations between greenness and health/mental health outcomes, this study found that increases in residential greenness were associated with lower odds of frequent binge drinking and lower odds of tobacco use in our study population, even after controlling for a range of suspected confounders. These findings speak to the importance of green spaces to help mitigate both substance using and abusing tendencies, and the potential for green spaces to be utilized in the delivery of addiction services.

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Appendices

Appendix A: Critical Appraisals

Critical Appraisal 1

Tillmann, S., Tobin, D., Avison, W., & Gilliland, J. (2018). Mental health benefits of interactions with nature in children and teenagers: a systematic review. *Journal of Epidemiology and Community Health*, *72*(10), 958–966. https://doi.org/10.1136/jech-2018-210436			
What Question did the Systematic Review address?	Does interacting with nature benefit the mental health of children and teenagers?		
	Population: children and teenagers (birth to 18 years-old) Intervention: interaction with nature (accessibility, exposure, or engagement) Outcome: mental health or component of mental health Study design: quantitative designs		
	Yes	No	Unclear
	Comments:	-	
Is it unlikely that important, relevant studies were missed?	Yes	No	Unclear
	Comments:	• Searched across 10 bibliographic databases for studies published between January 01, 1990 and March 01, 2017 • Search included English and French papers • Reference lists of included papers searched • Search terms were exhaustive. Outcome search terms included specific aspects of mental health. No search term for substance use, abuse, or addiction.	
Were the criteria used to select articles for inclusion appropriate?	Yes	No	Unclear
	Comments:	• Inclusion criteria were clearly defined.	

Were the included studies sufficiently valid for the type of question asked?	Yes	No	Unclear
	Comments:	• Bias assessed using NHLBI Assessment tools • 2 reviewers independently rated each study and assigned grade of : good, fair, poor ○ Nonunanimous decision resolved by third reviewer and majority rules.	
Were the results similar from study to study?	Yes	No	Unclear
	Comments:	• Heterogeneity discussed as a consequence of diverse study designs.	

Results	• Total Number of papers = 35
	  ○ 100 reported findings related to children's mental health
	  ○ 53 reported significant positive findings
	
	• Authors stratified results by exposure type
	  ○ Accessibility: defined as "ease of reaching destinations"
	  ▪ Implies likelihood of contact, not contact itself
	  • Exposure defined as: "being presented to view, having contact with or being subjected to some effect or influence of nature.
	  ▪ Implies direct contact. Authors argue that exposure in their review is largely a measure of incidental contact (i.e., time spent in nature, or use of a nature area).
	  • Engagement defined as: "Involvement or participation in an activity which is direct, intentional, and sustained." (p.961).
	
	  • *Among studies rated good and fair*
	  ▪ Emotional wellbeing: more nonsignificant than significant findings (13/23)		

	▪ ADD/ADHD: majority (7/13) identified significant positive associations • Significant associations for both 'access' and 'exposure' ▪ Overall mental health: majority (8/12) identified significant positive associations ▪ Self-esteem: more nonsignificant than significant findings (10/13) ▪ Stress: majority (4/5) identified significant positive associations ▪ Depression: more nonsignificant than significant findings (4/6) ▪ Resilience: majority (3/5) identified significant positive associations ▪ Health Related quality of life: majority (4/5) identified significant positive associations • Accessibility, exposure, engagement: engagement was most common form of interaction but had fewer significant than nonsignificant findings (20:24). Exposure had (16:9) and Accessibility (17:13) significant positive to negative associations. • *Limitations:* Subjective nature of Quality assessment for Observational studies ▪ Not as clear-cut as intervention based studies *OVERALL:* Stratification by exposure helpful but authors choice not universally accepted. Furthermore, categories don't seem mutually exclusive (exposure vs engagement) ▪ Engagement category is qualitatively distinct from others in that it is an intervention-based exposure (wilderness therapy, adventure therapy, for at risk youth) ▪ How did authors apply intervention type to particular studies?

Critical Appraisal 2

Mccormick, R. (2017). Does Access to Green Space Impact the Mental Well-being of Children: A Systematic Review. *Journal of Pediatric Nursing*, *37*, 3–7. https://doi.org/10.1016/j.pedn.2017.08.027			
What Question did the Systematic Review address?	Does access to greenspace impact the mental well-being of children?		
	Population: children (birth to 18 years-old) Intervention: access to green space Outcome: mental wellbeing Study design: Qualitative and Quantitative		
	Yes	No	Unclear
	Comments:	-	
Is it unlikely that important, relevant studies were missed?	Yes	No	Unclear
	Comments:	• Searched across 2 bibliographic databases for studies published between 2012 and 2017 • Search included English studies only • Minimal search terms were included: Ovid and PubMed search only included single key-words for the exposure and outcome ("green space" and "mental health") • Included qualitative and quantitative studies	
Were the criteria used to select articles for inclusion appropriate?	Yes	No	Unclear
	Comments:	• Inclusion criteria were poorly defined • 'Access' was never operationalized • 3 additional ('seminal') papers were included but how they were identified was never discussed	
	Yes	No	Unclear

<table>
<tr><td>Were the included studies sufficiently valid for the type of question asked?</td><td>Comments:</td><td colspan="2">Risk of bias not addressed</td></tr>
<tr><td rowspan="2">Were the results similar from study to study?</td><td>Yes</td><td>No</td><td>Unclear</td></tr>
<tr><td>Comments:</td><td colspan="2">Heterogeneity discussed as a consequence of diverse study designs.</td></tr>
<tr><td>Results</td><td colspan="3">Total number of papers = 12
Wellbeing and psychological distress: 3 studies investigated outcome based on SDQ.
Evidence suggests positive relationship between access and mental wellbeing, but statistical-significance of results is not discussed.
>20 min walk to green space associated with worse mental health
Attention restoration and ADHD: 4 studies investigated outcome.
Evidence suggests reduction of inattention and hyperactivity in children diagnosed with ADHD. Inverse relationship between diagnostic scores for ADHD total and inattention scores
statistical-significance of results is not discussed
OVERALL: Review suggest positive associations between green space and mental health, however:
Risk of bias is unclear
‘access’ is ambiguous and included studies cover multiple forms of engagement with green space (i.e., the interventions are diverse).</td></tr>
</table>

Critical Appraisal 3

Gert-Jan Vanaken, & Marina Danckaerts. (2018). Impact of Green Space Exposure on Children's and Adolescents' Mental Health: A Systematic Review. *International Journal of Environmental Research and Public Health*, *15*(12). https://doi.org/10.3390/ijerph15122668			
What Question did the Systematic Review address?	Is there an association between green space exposure and children's and adolescent's mental health and neurocognitive development?		
	Population: children, adolescents, young adults (birth to 25 years-old) Intervention: exposure to green space Outcome: mental health/neurocognitive development Study design: observational studies		
	Yes	No	Unclear
	Comments:	-	
Is it unlikely that important, relevant studies were missed?	Yes	No	Unclear
	Comments:	• Searched across 2 bibliographic databases with no restriction on publication date • Search included English studies only • Reference lists of included papers searched • Included multiple search terms for both exposure and outcome. • Outcome search terms remained general however, including only: 'mental health', 'wellbeing' and 'development'.	
Were the criteria used to select articles for inclusion appropriate?	Yes	No	Unclear
	Comments:	• Inclusion criteria were clearly defined	
	Yes	No	Unclear

<table>
<tr><td>Were the included studies sufficiently valid for the type of question asked?</td><td>Comments:</td><td colspan="2">Risk of bias was not formally addressed
But a process for evidence evaluation was outlined: associations between green space and outcomes would be described based on the number of studies finding a beneficial finding compared to the total number of studies that reported on that finding</td></tr>
<tr><td rowspan="2">Were the results similar from study to study?</td><td>Yes</td><td>No</td><td>Unclear</td></tr>
<tr><td>Comments:</td><td colspan="2">Authors discuss difficulty of quantitative comparison of results given large variation in exposure mapping and outcome assessment</td></tr>
<tr><td>Results</td><td colspan="3">Total number of studies = 21
12 cross-sectional, 7 longitudinal, 2 ecological
Emotional and Behavioral Difficulties:
7 out of 9 studies found a positive association between green space and Total Difficulties Score (TDS), a subset of four of the five SDQ domains (emotional symptoms, peer problems, hyperactivity/inattention, conduct problems)
For SDQ in general, strongest results were found for the hyperactivity and inattention domain (5 out of 6)
Positive association with increasing green space quantity and quality and internalizing and externalizing subscales of SDQ (2 of 2)
Smaller associations in peer problems (4 out of 5)
Less consistency in conduct and emotional (2 out of 5)
Mixed for prosocial behavior domain (1 out of 3)
For different types of green space exposure, a shorter distance to the nearest green space and access to a private garden were more strongly associated with the SDQ than the</td></tr>
</table>

	average amount of green space at a neighborhood level. 1 of 1 studies found that short and long term green space exposure was associated with a decrease in aggressive behavior 1 of 1 studies found a decrease in depressive symptoms (measured by residential neighborhood greenness) 1 of 1 studies found NO association between green space exposure and mental health as measured through the General Health Questionnaire (GHQ) *Mental Wellbeing:* 1 of 1 found that quantity and size of urban green space was positively associated with health-related quality of life 1 of 1 found that time spent in green spaces was associated with higher life satisfaction, well-being and happiness 2 other studies found no associations between green space and mental wellbeing (exposure measured via: average greenness in 5000m buffer of schools, greenspace access) *Neurocognitive Development:* 1 study found inverse association between green space (land coverage) and deficits in visio-motor and language development 1 study found improvements in working memory and a reduction in inattentiveness among children exposed to higher levels of surrounding greenness • BUT no association found among residential greenness compared to school and combined category 1 study found association between residential greenness and attention 1 study found association between green space exposure and autism prevalence Results more pronounced in areas with greatest road density AGE variations Authors argue that the 'exposure mechanism' has different implications for different age groups. 'Access' (closeness to park and availability of private garden) seems to be more important measure for children while '

	residential Greenness' and 'quality' seems to be more important for adolescents and older children OVERALL: Review suggest positive associations between green space and mental health • Authors discus possibility of reverse causality and the importance of understanding the role of *parental mental-health* • Authors discus potential mediators: air pollution, physical activity, social interaction • Criticism: authors didn't always tease out what was used to measure '*green space exposure*', instead they reported results in context of exposure in general (e.g., SDQ results) ▪ For SDQ studies 'exposure' was diverse: distance to green space, amount within 500m buffer, amount measured by LSOA, average greenness within 300m. ▪ Aside from significance, magnitude of effect was not discussed

Critical Appraisal 4

G Houlden, V., Weich, S., Porto de Albuquerque, J., Jarvis, S., & Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: A systematic review.(Research Article). *PLoS ONE*, *13*(9), e0203000. https://doi.org/10.1371/journal.pone.0203000			
What Question did the Systematic Review address?	Is there an association between green space and mental wellbeing in adults?		
	Population: adults (age 16+) Intervention: any exposure to green space Outcome: mental wellbeing (using validated measure) Study design: all study designs were considered		
	Yes	No	Unclear
	Comments:	-	
	Yes	No	Unclear

Is it unlikely that important, relevant studies were missed?	Comments:	• Searched across 5 bibliographic databases for studies published between January 1, 1980 and January 31, 2018 • Search included English studies only • Included multiple search terms for both exposure and outcome. • Outcome search terms focused on positive mental health, including only: 'wellbeing', 'happiness' 'satisfaction with life'.	
Were the criteria used to select articles for inclusion appropriate?	Yes	No	Unclear
	Comments:	• Inclusion criteria were clearly defined	
Were the included studies sufficiently valid for the type of question asked?	Yes	No	Unclear
	Comments:	• Quality assessment through Newcastle-Ottawa Scale (NOS) and Cochrane Risk of Bias tool (RoB)	
Were the results similar from study to study?	Yes	No	Unclear
	Comments:	• Significant heterogeneity in terms of exposure and outcome measurement	
Results	• *Number of studies = 52* ○ 4 controlled case studies, 4 uncontrolled case studies, 6 longitudinal, 1 ecological, 37 cross-sectional *Green Space 'exposure' types:* Authors identified and stratified findings within 6 types of green space 'exposure': 1. amount of local green space/ green space cover, 2. green space type, 3. green space views, 4. green space visits, 5. proximity and self-reported access, 6. subjective connection with nature.		

	Mental Wellbeing: 14 studies measured both hedonic and eudaimonic mental wellbeing (Warwick Edinberg mental wellbeing scale). Remaining studies measure aspects of mental wellbeing *Amount of Local Green space (lower Layer super Output Area (LSOA):* • 21 studies utilized this exposure • 4 investigated hedonic and eudaimonic mental wellbeing. 3 of 4 found no statistically significant association • 4 found significant associations with life satisfaction. But the magnitude of the effect was small ▪ Based on good quality studies, authors argue there is adequate evidence for association between amount of local area green space and life satisfaction in urban areas. • 8 investigated mental distress (with GHQ). ▪ Adequate evidence for association between local area green space and lower GHQ • Effect sizes varies considerably *Green space Type:* • 10 studies utilized this exposure • Problem: lack of consensus and consistency between 'types'. Types included (serene, wild, lush, spacious, and cultural), (natural), (mountainous, woodland, semi-natural) ▪ Overall evidence considered limited *Green space Visits (including adventure therapy):* • 17 studies utilized this exposure • Mixed findings for hedonic and eudaimonic mental wellbeing • 4 found greater quality of life and mental health improved ▪ Overall evidence considered limited *Green space views:* • 3 studies utilized this exposure

	▪ Overall evidence considered inadequate (Mixed quality and small samples) *Green space Accessibility:* • 8 studies utilized this exposure • Several studies found an association but measurement of both exposure and outcome, even within this category, varied greatly ▪ Overall evidence considered limited *Subjective Connection:* • 7 studies utilized this exposure • Consistent positive associations for satisfaction with life, happiness, affect, however, 5 of 7 were poor quality ▪ Overall evidence considered inadequate OVERALL: • Evidence of association between green space and mental wellbeing, in particular hedonic wellbeing • Adequate evidence for urban green space and life-satisfaction • Limited evidence for green space types, visits, and accessibility. • Adequate evidence for association with green space and lower GHQ scores

Critical Appraisal 5

Mireia Gascon, Margarita Triguero-Mas, David Martínez, Payam Dadvand, Joan Forns, Antoni Plasència, & Mark J. Nieuwenhuijsen. (2015). Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *International Journal of Environmental Research and Public Health*, *12*(4), 4354–4379. https://doi.org/10.3390/ijerph120404354	
What Question did the Systematic Review address?	Is there an association between exposure to green /blue space and long-term mental health?
	Population: children and adults (age range not specified) Intervention: exposure to green space (remote sensing data, land use/cover, assessment by trained auditors) Outcome: mental health Study design: all study designs were considered

	Yes	No	Unclear
	Comments:	-	
Is it unlikely that important, relevant studies were missed?	Yes	No	Unclear
	Comments:	• Searched across 2 bibliographic databases • Search included English studies only • Included multiple search terms for both exposure and outcome. • Outcome search terms included specific and general mental health outcomes,	
Were the criteria used to select articles for inclusion appropriate?	Yes	No	Unclear
	Comments:	• Inclusion criteria were clearly defined	
Were the included studies sufficiently valid for the type of question asked?	Yes	No	Unclear
	Comments:	• Quality assessment through 11 dimension scale. • Quality evaluated by two independent reviewers and a third to settle disputes	
Were the results similar from study to study?	Yes	No	Unclear
	Comments:	• Significant heterogeneity in terms of exposure and outcome measurement • Authors tried to conduct MA for association between surrounding greenness and Mental health ○ Not enough information provided in papers and unable to obtain all results directly from authors	

Results	• Number of studies = 28
	  ○ 6 longitudinal, one ecological, 21 cross-sectional
	
	Authors separately evaluated evidence based on age of the study populations and by type of green space exposure: 1. surrounding green space, 2. access to green space, 3. quality of green space, 4. Blue space (amount, access, quality).
	
	Strength of evidence classified into: sufficient, limited, inadequate, lack of association
	
	Breakdown of study design: 6 longitudinal, one ecological, 21 cross-sectional
	
	Surrounding greenness: (percentage of green space in particular buffer or NDVI)
	• 22 studies evaluated mental health benefits of this exposure
	• 4 studies assessed relationship in children (outcome: emotional and behavioral problems)
	• Evidence classified as inadequate (mixed findings)
	
	• 18 studies assessed relationship in adults
	  ▪ 13 found reduced risk with poor mental health or a mental health related disorder
	  • One study found relationship varied by age and gender
	  ▪ Overall evidence classified as limited
	
	Access to Green space: (distance to nearest green space, park, or open area)
	• 3 studies assessed relationship in children
	• Evidence classified as inadequate (mixed findings, limited studies)
	
	• Studies on adults assessed depression, anxiety, stress, and mood disorders
	  ▪ Found mixed results: 3 found associations, 2 found no association,

	1 found associations for subsets of the population (black teens) ▪ Evidence classified as inadequate *Quality of Green Space: (non-validated audit tools)* • 2 studies assessed this relationship • One study noted reductions for physically active women • Second study looked at characteristics of green space in street, but actual green space measure (quantity) was poorly defined. *Blue Spaces:* • 3 cross-sectional studies assessed this exposure • Mixed findings: one study found no association with mental health for small (1km, 3km) buffers. Another study found positive mental health benefits for people within 5km of a coast. • Evidence classified as inadequate *Overall:* • Limited evidence for surrounding greenness and mental health in adults and inadequate evidence for all other exposures and studies involving children • Authors argue that the absence of a standardized approach to measure green space exposure is problematic. ▪ Definitions of 'access' and 'greenness' vary, and sometimes overlap ▪ Authors argue that there are no recommendations for which indicators to use and that different definitions can and do lead to different conclusions • Depending on the underlying mechanism, or set of mechanisms, different exposures could lead to different results • All studies on children used the same tool to evaluate mental health (SDQ), authors argue other tools might give better more refined

	information (e.g., child behavior checklist CBCL) • Authors argue that several studies support notion of social determinants of health and that is seems individuals with low SES are more likely to benefit from exposure than those from high SES • <u>Criticism:</u> While authors discus results for children and adults separately, the division is somewhat arbitrary. ▪ Children category includes studies exclusively focused on children BUT Adult category includes adults 15+ *or* population irrespective of age

Appendix B: Bivariate Tables

		n(%), mean (sd)	
	Total	**no**	**yes**
	N=14,063	N=3,710	N=10,353
4 quantiles of residential greenness			
1	3,936 (28.0%)	1,062 (28.7%)	2,874 (27.8%)
2	3,298 (23.5%)	917 (24.7%)	2,381 (23.0%)
3	3,633 (25.9%)	954 (25.7%)	2,679 (25.9%)
4	3,184 (22.7%)	773 (20.9%)	2,411 (23.3%)
age			
15-18 years old	5,489 (39.0%)	2,569 (69.2%)	2,920 (28.2%)
19-21 years old	3,377 (24.0%)	527 (14.2%)	2,850 (27.5%)
22-25 years old	5,197 (37.0%)	614 (16.5%)	4,583 (44.3%)
sex			
female	7,052 (50.1%)	1,843 (49.7%)	5,209 (50.3%)
male	7,011 (49.9%)	1,867 (50.3%)	5,144 (49.7%)
total household income before taxes - best estimate	103793.5 (133967.8)	103696.9 (132251.3)	103828.1 (134583.8)
highest level of education - respondent, 3 levels			
< secondary school	5,039 (36.0%)	2,433 (65.9%)	2,606 (25.3%)
secondary school	4,962 (35.5%)	835 (22.6%)	4,127 (40.1%)
post-secondary	3,987 (28.5%)	423 (11.5%)	3,564 (34.6%)
cultural / racial background			
white	9,431 (67.8%)	1,870 (51.0%)	7,561 (73.8%)
non-white	4,482 (32.2%)	1,794 (49.0%)	2,688 (26.2%)
landed immigrant status in canada			
non-immigrant	11,533 (82.8%)	2,656 (72.4%)	8,877 (86.5%)
immigrant	2,400 (17.2%)	1,014 (27.6%)	1,386 (13.5%)
population centre or rural area classification			
small pop. (1,000-29,000)	3,546 (25.2%)	784 (21.1%)	2,762 (26.7%)
medium pop. (30,000-99,000)	2,237 (15.9%)	562 (15.1%)	1,675 (16.2%)
large pop. (1000,000 +)	8,280 (58.9%)	2,364 (63.7%)	5,916 (57.1%)
employment status			
employed	5,489 (39.5%)	630 (17.2%)	4,859 (47.4%)
student	6,541 (47.0%)	2,491 (68.1%)	4,050 (39.5%)
un-employed	674 (4.8%)	140 (3.8%)	534 (5.2%)
other	1,199 (8.6%)	397 (10.9%)	802 (7.8%)
body mass index (self-reported)	23.7 (5.0)	22.8 (4.9)	24.0 (5.0)
considers self heterosexual / homosexual / bisexual			
heterosexual	12,270 (92.3%)	3,106 (94.1%)	9,164 (91.7%)
homosexual	319 (2.4%)	58 (1.8%)	261 (2.6%)
bisexual	705 (5.3%)	136 (4.1%)	569 (5.7%)
has a mood disorder (depression, bipolar, mania, dysthymia)			
no	12,527 (89.3%)	3,416 (92.5%)	9,111 (88.2%)
yes	1,502 (10.7%)	278 (7.5%)	1,224 (11.8%)
has an anxiety disorder (phobia, ocd, panic)			
no	12,075 (86.0%)	3,280 (88.7%)	8,795 (85.1%)
yes	1,958 (14.0%)	416 (11.3%)	1,542 (14.9%)
perceived health	3.9 (0.9)	4.0 (0.9)	3.9 (0.9)
perceived life stress	3.2 (0.9)	3.4 (1.0)	3.2 (0.9)
marijuana use			
no	12,351 (89.2%)	3,524 (98.0%)	8,827 (86.1%)
yes	1,497 (10.8%)	71 (2.0%)	1,426 (13.9%)
smoker			
no	11,732 (83.4%)	3,553 (95.8%)	8,179 (79.0%)
yes	2,328 (16.6%)	156 (4.2%)	2,172 (21.0%)

Binge

	n(%), mean (sd)		
	Total	**no**	**yes**
	N=13,986	N=6,555	N=7,431
4 quantiles of residential greenness			
1	3,912 (28.0%)	1,811 (27.7%)	2,101 (28.3%)
2	3,280 (23.5%)	1,594 (24.3%)	1,686 (22.7%)
3	3,613 (25.9%)	1,719 (26.2%)	1,894 (25.5%)
4	3,170 (22.7%)	1,425 (21.8%)	1,745 (23.5%)
age			
15-18 years old	5,460 (39.0%)	3,797 (57.9%)	1,663 (22.4%)
19-21 years old	3,359 (24.0%)	1,136 (17.3%)	2,223 (29.9%)
22-25 years old	5,167 (36.9%)	1,622 (24.7%)	3,545 (47.7%)
sex			
female	7,010 (50.1%)	3,301 (50.4%)	3,709 (49.9%)
male	6,976 (49.9%)	3,254 (49.6%)	3,722 (50.1%)
total household income before taxes - best estimate	103671.3 (134031.3)	102644.2 (121063.3)	104577.3 (144509.9)
highest level of education - respondent			
< secondary school	5,010 (36.0%)	3,535 (54.3%)	1,475 (19.9%)
secondary school	4,931 (35.4%)	1,847 (28.3%)	3,084 (41.7%)
post-secondary	3,971 (28.5%)	1,134 (17.4%)	2,837 (38.4%)
cultural / racial background			
white	9,376 (67.8%)	3,715 (57.3%)	5,661 (76.9%)
non-white	4,463 (32.2%)	2,765 (42.7%)	1,698 (23.1%)
landed immigrant status in canada			
non-immigrant	11,460 (82.7%)	4,860 (74.9%)	6,600 (89.6%)
immigrant	2,396 (17.3%)	1,631 (25.1%)	765 (10.4%)
population centre or rural area classification			
small pop. (1,000-29,000)	3,526 (25.2%)	1,448 (22.1%)	2,078 (28.0%)
medium pop. (30,000-99,000)	2,222 (15.9%)	1,010 (15.4%)	1,212 (16.3%)
large pop. (1000,000 +)	8,238 (58.9%)	4,097 (62.5%)	4,141 (55.7%)
employment status			
employed	5,457 (39.5%)	1,608 (24.8%)	3,849 (52.3%)
student	6,514 (47.1%)	3,899 (60.2%)	2,615 (35.5%)
un-employed	670 (4.8%)	285 (4.4%)	385 (5.2%)
other	1,188 (8.6%)	680 (10.5%)	508 (6.9%)
body mass index (self-reported)	23.7 (5.0)	23.1 (5.0)	24.2 (4.9)
considers self heterosexual / homosexual / bisexual			
heterosexual	12,213 (92.3%)	5,595 (93.2%)	6,618 (91.5%)
homosexual	319 (2.4%)	120 (2.0%)	199 (2.8%)
bisexual	699 (5.3%)	286 (4.8%)	413 (5.7%)
has a mood disorder (depression, bipolar, mania, dysthymia)			
no	12,464 (89.3%)	5,966 (91.3%)	6,498 (87.6%)
yes	1,488 (10.7%)	568 (8.7%)	920 (12.4%)
has an anxiety disorder (phobia, ocd, panic)			
no	12,020 (86.1%)	5,732 (87.7%)	6,288 (84.7%)
yes	1,936 (13.9%)	802 (12.3%)	1,134 (15.3%)
perceived health	3.9 (0.9)	3.9 (0.9)	3.9 (0.9)
perceived life stress	3.2 (0.9)	3.3 (0.9)	3.1 (0.9)
smoker			
no	11,680 (83.5%)	6,139 (93.7%)	5,541 (74.6%)
yes	2,303 (16.5%)	415 (6.3%)	1,888 (25.4%)
marijuana use			
no	12,297 (89.2%)	6,129 (95.9%)	6,168 (83.5%)
yes	1,483 (10.8%)	262 (4.1%)	1,221 (16.5%)

Smoking

	n(%), mean (sd)		
	Total	**no**	**yes**
	N=14,077	N=11,749	N=2,328
4 quantiles of residential greenness			
1	3,941 (28.0%)	3,215 (27.4%)	726 (31.2%)
2	3,302 (23.5%)	2,736 (23.3%)	566 (24.3%)
3	3,635 (25.8%)	3,066 (26.1%)	569 (24.5%)
4	3,187 (22.7%)	2,722 (23.2%)	465 (20.0%)
age			
15-18 years old	5,497 (39.0%)	5,065 (43.1%)	432 (18.6%)
19-21 years old	3,378 (24.0%)	2,658 (22.6%)	720 (30.9%)
22-25 years old	5,202 (37.0%)	4,026 (34.3%)	1,176 (50.5%)
sex			
female	7,059 (50.1%)	6,023 (51.3%)	1,036 (44.5%)
male	7,018 (49.9%)	5,726 (48.7%)	1,292 (55.5%)
total household income before taxes - best estimate	103778.5 (134049.3)	108674.9 (141020.2)	79067.3 (86973.6)
highest level of education - respondent			
< secondary school	5,044 (36.0%)	4,381 (37.5%)	663 (28.7%)
secondary school	4,968 (35.5%)	3,972 (34.0%)	996 (43.2%)
post-secondary	3,990 (28.5%)	3,341 (28.6%)	649 (28.1%)
cultural / racial background			
white	9,440 (67.8%)	7,804 (67.1%)	1,636 (71.1%)
non-white	4,485 (32.2%)	3,820 (32.9%)	665 (28.9%)
landed immigrant status in canada			
non-immigrant	11,542 (82.8%)	9,509 (81.7%)	2,033 (88.1%)
immigrant	2,404 (17.2%)	2,129 (18.3%)	275 (11.9%)
population centre or rural area classification			
small pop. (1,000-29,000)	3,550 (25.2%)	2,828 (24.1%)	722 (31.0%)
medium pop. (30,000-99,000)	2,237 (15.9%)	1,806 (15.4%)	431 (18.5%)
large pop. (1000,000 +)	8,290 (58.9%)	7,115 (60.6%)	1,175 (50.5%)
employment status			
employed	5,491 (39.5%)	4,298 (37.0%)	1,193 (51.9%)
student	6,549 (47.1%)	5,941 (51.1%)	608 (26.5%)
un-employed	678 (4.9%)	477 (4.1%)	201 (8.7%)
other	1,199 (8.6%)	903 (7.8%)	296 (12.9%)
body mass index (self-reported)	23.7 (5.0)	23.6 (4.9)	24.4 (5.2)
considers self heterosexual / homosexual / bisexual			
heterosexual	12,280 (92.3%)	10,317 (93.2%)	1,963 (88.0%)
homosexual	319 (2.4%)	245 (2.2%)	74 (3.3%)
bisexual	705 (5.3%)	512 (4.6%)	193 (8.7%)
has a mood disorder (depression, bipolar, mania, dysthymia)			
no	12,540 (89.3%)	10,731 (91.5%)	1,809 (78.0%)
yes	1,503 (10.7%)	992 (8.5%)	511 (22.0%)
has an anxiety disorder (phobia, ocd, panic)			
no	12,086 (86.0%)	10,337 (88.2%)	1,749 (75.2%)
yes	1,961 (14.0%)	1,385 (11.8%)	576 (24.8%)
perceived health	3.9 (0.9)	4.0 (0.9)	3.6 (1.0)
perceived life stress	3.2 (0.9)	3.3 (0.9)	3.0 (0.9)
marijuana use			
no	12,362 (89.2%)	10,585 (91.6%)	1,777 (77.2%)
yes	1,498 (10.8%)	974 (8.4%)	524 (22.8%)
binge drinking (past 12 months)			
no	6,554 (46.9%)	6,139 (52.6%)	415 (18.0%)
yes	7,429 (53.1%)	5,541 (47.4%)	1,888 (82.0%)

Marijuana

	n(%), mean (sd)		
	Total	**no**	**yes**
	N=13,862	N=12,364	N=1,498
4 quantiles of residential greenness			
1	3,914 (28.3%)	3,554 (28.8%)	360 (24.1%)
2	3,248 (23.5%)	2,892 (23.4%)	356 (23.8%)
3	3,561 (25.7%)	3,069 (24.8%)	492 (32.9%)
4	3,127 (22.6%)	2,841 (23.0%)	286 (19.1%)
age			
15-18 years old	5,396 (38.9%)	5,005 (40.5%)	391 (26.1%)
19-21 years old	3,326 (24.0%)	2,872 (23.2%)	454 (30.3%)
22-25 years old	5,140 (37.1%)	4,487 (36.3%)	653 (43.6%)
sex			
female	6,949 (50.1%)	6,253 (50.6%)	696 (46.5%)
male	6,913 (49.9%)	6,111 (49.4%)	802 (53.5%)
total household income before taxes - best estimate	103778.7 (134401.6)	103627.9 (136669.5)	105023.6 (114005.7)
highest level of education - respondent			
< secondary school	4,913 (35.6%)	4,545 (37.0%)	368 (24.7%)
secondary school	4,911 (35.6%)	4,242 (34.5%)	669 (44.9%)
post-secondary	3,966 (28.8%)	3,513 (28.6%)	453 (30.4%)
cultural / racial background			
white	9,294 (67.8%)	8,208 (67.1%)	1,086 (73.1%)
non-white	4,420 (32.2%)	4,021 (32.9%)	399 (26.9%)
landed immigrant status in canada			
non-immigrant	11,346 (82.6%)	10,001 (81.7%)	1,345 (90.5%)
immigrant	2,385 (17.4%)	2,243 (18.3%)	142 (9.5%)
population centre or rural area classification			
small pop. (1,000-29,000)	3,493 (25.2%)	3,140 (25.4%)	353 (23.6%)
medium pop. (30,000-99,000)	2,208 (15.9%)	1,892 (15.3%)	316 (21.1%)
large pop. (1000,000 +)	8,161 (58.9%)	7,332 (59.3%)	829 (55.3%)
employment status			
employed	5,458 (39.8%)	4,711 (38.5%)	747 (50.3%)
student	6,435 (47.0%)	5,914 (48.4%)	521 (35.1%)
un-employed	669 (4.9%)	563 (4.6%)	106 (7.1%)
other	1,144 (8.3%)	1,034 (8.5%)	110 (7.4%)
body mass index (self-reported)	23.7 (5.0)	23.7 (5.0)	24.1 (5.1)
considers self heterosexual / homosexual / bisexual			
heterosexual	12,256 (92.3%)	10,960 (92.8%)	1,296 (88.2%)
homosexual	319 (2.4%)	272 (2.3%)	47 (3.2%)
bisexual	703 (5.3%)	576 (4.9%)	127 (8.6%)
has a mood disorder (depression, bipolar, mania, dysthymia)			
no	12,384 (89.5%)	11,197 (90.8%)	1,187 (79.5%)
yes	1,447 (10.5%)	1,140 (9.2%)	307 (20.5%)
has an anxiety disorder (phobia, ocd, panic)			
no	11,978 (86.6%)	10,791 (87.5%)	1,187 (79.2%)
yes	1,859 (13.4%)	1,548 (12.5%)	311 (20.8%)
perceived health	3.9 (0.9)	3.9 (0.9)	3.7 (0.9)
perceived life stress	3.2 (0.9)	3.2 (0.9)	3.1 (0.9)
smoker			
no	11,559 (83.4%)	10,585 (85.6%)	974 (65.0%)
yes	2,301 (16.6%)	1,777 (14.4%)	524 (35.0%)
binge drinking (past 12 months)			
no	6,391 (46.4%)	6,129 (49.8%)	262 (17.7%)
yes	7,389 (53.6%)	6,168 (50.2%)	1,221 (82.3%)

Appendix C: Unadjusted Multinomial Regression Results

Alcohol Frequency

Characteristic	**Rarely** OR 95% C.I.	**Monthly** OR 95% C.I.	**Weekly** OR 95% C.I.
Residential Greenness			
Quartile 1	*reference*	*reference*	*reference*
Quartile 2	1.07 (0.93, 1.22)	0.96 (0.84, 1.09)	0.89 (0.78, 1.01)
Quartile 3	1.15* (1.01, 1.32)	1.06 (0.94, 1.20)	0.94 (0.83,1.06)
Quartile 4	1.31** (1.14, 1.50)	1.21**(1.06, 1.37)	0.99 (0.87, 1.13)

[1]reference category for outcome = 'Never'
[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Binge Drinking Frequency

Characteristic	**Rarely** OR 95% C.I.	**Monthly** OR 95% C.I.	**Weekly** OR 95% C.I.
Residential Greenness			
Quartile 1	*reference*	*reference*	*reference*
Quartile 2	0.98 (0.88, 1.10)	0.84* (0.74, .96)	0.83* (0.69, 0.99)
Quartile 3	1.02 (0.91, 1.13)	0.88 (0.79, 1.00)	0.88 (0.73, 1.05)
Quartile 4	1.15* (1.03, 1.29)	0.99 (0.87, 1.12)	0.87 (0.72, 1.05)

[1]reference category for outcome = 'Never'
[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Smoking Intensity

Characteristic	**LOW** OR 95% C.I.	**Moderate** OR 95% C.I.	**Heavy** OR 95% C.I.
Residential Greenness			
Quartile 1	*reference*	*reference*	*reference*
Quartile 2	0.89 (0.77, 1.01)	0.99 (0.72, 1.37)	1.11 (0.77, 1.61)
Quartile 3	0.78** (0.68, 0.89)	0.91 (0.67, 1.25)	1.14 (0.80, 1.63)
Quartile 4	0.69** (0.60, 0.79)	1.18 (0.87, 1.60)	0.90 (0.61, 1.33)

[1]reference category for outcome = 'Never'
[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

Marijuana Intensity **Characteristic**	**Rarely** OR 95% C.I.	**Weekly** OR 95% C.I.	**Daily** OR 95% C.I.
Residential Greenness			
Quartile 1	*reference*	*reference*	*reference*
Quartile 2	1.24* (1.00, 1.53)	1.30 (0.96, 1.78)	1.03 (0.71, 1.49)
Quartile 3	1.61** (1.33, 1.97)	1.48* (1.10, 1.99)	1.31 (0.93, 1.84)
Quartile 4	1.19 (0.96, 1.47)	0.73 (0.51, 1.05)	0.81 (0.55, 1.21)

[1]reference category for outcome = 'Never'

[2] * statistical significance at p-value < 0.05, ** statistical significance at p-value < 0.01

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Publications

1. Wiley, E., Seabrook, J., Gilliland, J., Anderson, K., & Stranges, S. (2020). Green space and substance use and addiction: A new frontier. Addictive Behaviors, 100, 106155. https://doi.org/10.1016/j.addbeh.2019.106155