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Neighborhood Nature

A Quantitative study on the links between Neighborhood Greenspace and Mental Health in the Adolescents of Oslo

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Acknowledgement

The variables that allowed for the completion is this academic requirement will be presented in this section. Other variables may have been omitted, but the author of the present thesis reports that it is an honest lapse of memory and hopes that it will not affect the integrity of the analyses.

Part of this accomplishment can be accounted for by the presence of highly qualified professors the author had had the privileged of learn from. This association is partially mediated by the assistance of the non-teaching staff in the departments SAM and NOVA of Oslo Met (formerly known as HiOA).

A substantial portion of the outcome variable is accounted for by having an awesome supervisor who agreed to take on the challenge of guiding a student who was, up until a few months ago, completely lost in the concepts of quantitative data analysis. An equal portion can be accounted for by having a classmate who was crazy enough to also take the quantitative route but has made herself available whenever the author feels his mind is about to collapse in the weight of uncertainty. Together, these two variables have been instrumental, not only in the completion of the present thesis, but also in keeping the author's sanity intact.

A certain percentage is accounted for by having family and friends who've been a constant reminder of how life is outside work, and how it will go on when the solitary endeavor of writing a quantitative thesis is finally over. The drama they provided, some of which are of high comedic value, reminded the author how fun it was playing human.

The predictor with the largest beta coefficient is having a supportive partner who've been stretching the limits of his patience to accommodate the author's quirks, as well as always maintaining a positive attitude even when he had no idea what the author was rambling about. This relationship was enhanced by a suppressor variable in a form of having the best dog in the world who is always waiting to be taken on long walks in the forest near the author's home. Not only did the suppressor variable provide much needed respite from working in front of the pc, it also helped the author shed some pounds to prepare him for the summer.

In the order of being mentioned first, the variables Rune, Ivan, Randi, Dag, Simon, Einar, Stuart, Anders, Åsmund, Sohlbin, Mama, Bente and the kids, Etty and family, Joann and family, the guys at Le Kanang, Tim, and Charlie the dog, can account for nearly 99% of the outcome variable.

The analyses indicate that after the present thesis was finished, the author is overwhelmed with emotions that are hard to define and characterized only by an intense desire to thoroughly clean the house and play DOTA 2 afterwards.

Abstract

The aim of this master thesis was to examine the relationship between neighborhood greenspace and mental health in the senior high school (*videregående*) students of Oslo. This inquiry was prompted by reports showing an increase in the self-reported symptoms of depression in the population of interest, as well as the need to expand knowledge on the role physical environments play in predicting mental health outcomes. Previous studies on restorative environments have found associations between neighborhood greenspace and improved mental health. However, more research is needed with regards to how this relationship is moderated by one's gender and socioeconomic status.

Data from the 2015 Young in Oslo survey (N=10,255) by the Norwegian Social Research (NOVA), and geospatial data from the Urban EEA project of the Norwegian Institute of Nature Research were utilized to gain insights on the relationship between the dependent variables *Depressed Mood* and *Anxiety,* background variables *Gender* and *Family Affluence,* environmental satisfaction variables *Neighborhood* and *School Satisfaction*, and variables indicating neighborhood greenspace availability, specifically *Average Neighborhood Greenness, Natural Cover* and *Tree Canopy Cover*.

The results indicate that there are substantial gender differences in terms of how the variables interact to predict mental health outcomes. For the male respondents, none of the neighborhood greenspace measures were significant predictors of *Depressed mood* and *Anxiety* when controlling for *Family Affluence* and environmental satisfaction. For the female respondents, *Natural Cover* and *Tree Canopy Cover* were significant predictors of *Depressed mood* and *Anxiety,* while *Family Affluence* was mediated by *Neighborhood Satisfaction.* Furthermore, post hoc analysis offered support that reciprocal suppression was present between the neighborhood greenspace measures and *Neighborhood Satisfaction* for the female group. The suppression effect was not observed in the male group.

Methodological issues are addressed in this thesis, as well as presenting suggestions for further research; which includes improvements in the operationalization of the adolescents' immediate environment, and other currently available data which can be used in future studies investigating the different pathways between greenspace and health outcomes for the adolescents of Oslo.

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1. Introduction

It is generally recognized that there is a wide range of social determinants of health that are associated with urbanity (WHO 2008, 2012). The political, social, and physical environments people live with, as well as their personal characteristics, in concert, determine mental health outcomes in various ways (WHO 2005, 2017a). One's gender and socioeconomic position often dictates the kind of educational and health services one has access to, as well as limiting the choice of neighborhoods one can afford to live in. Health disparities between the rich and poor are often proportional to the differences in their income, educational level, and the kind of social capital they have access to (Marmot 2010; Lin and Kickbusch 2017). Consequently, there is a common pattern in many cities where features in the physical environment that can promote health are not equitably distributed (CABE 2010; WHO 2012). One such feature are *greenspaces* (Thompson et al. 2016; WHO 2017b). Based on a massive body of literature spanning decades, greenspaces have now been linked to various health outcomes through four pathways: *stress reduction and psychological restoration*, improved *social cohesion*, increased *physical activity*, and minimizing the *exposure to pollution* and other harmful factors in the urban environment (Hartig et al. 2014; Thompson et al. 2016). These pathways provide an explanatory model in which the numerous positive health outcomes associated with greenspaces are achieved; such as improved mental health and cognitive functioning (T Sugiyama et al. 2008; Beyer et al. 2014; Amoly et al. 2015; R. J. Mitchell et al. 2015), reduced cardiovascular morbidity and mortality (R. Mitchell and Popham 2008; Gascon et al. 2016), reduction of prevalence in type 2 diabetes (T Astell-Burt, Feng, and Kolt 2014; Thiering et al. 2016), and improved pregnancy outcomes (Banay et al. 2017).

Of the several pathways identified, this thesis will primarily focus on the *stress reduction and psychological restoration* pathway. Though the different pathways often interact depending on the context, consensus from available literature suggests that the pathway in focus offers more compelling evidence of greenspaces' capacity to improve mental health compared to the others (de Vries 2010; Amoly et al. 2015; Gascon et al. 2015).

This area of inquiry is particularly important and timely in light of the 2015 Young in Oslo report showing a marked increase in the psychological problems among adolescent girls in the city (Andersen and Bakken 2015). Although Oslo is still very good place to grow up in, with most adolescents reporting high satisfaction with various aspects of their lives, the number of those who report severe depressive symptoms have doubled since 1996 (ibid.). These numbers find resonance in national-level data where, past the age of twelve, two out three who live with psychological problems are girls (NIPH 2016).

This local reality in Oslo is part of a global trend. The World Health Organization (WHO) projections show that mental disorders are increasing and will account for nearly 15% of the disability-adjusted life-years (DALYs) lost due to illness by 2020; with depressive and anxiety disorders as the most common diagnostic categories globally (WHO 2017a). As of 2015, the WHO estimates that around 322 million people live with depression, and around 264 million are affected by anxiety disorders. These numbers correspond to roughly 4.4% and 3.6% of the global population respectively (ibid).

Finding innovative solutions to complex public health issues require a multidisciplinary approach (WHO 2003). Health in all policies include the exploration of how the physical environment, as a social determinant of health, affect urban dwellers (Lin and Kickbusch 2017). This includes investigating how *within* city variations in physical environments have become an avenue for mental health inequality to arise.

Previous research on the adolescents of Oslo have found that major differences in their living conditions and level of family resources can affect their well-being. Those who live in rented houses and move frequently tend to be less satisfied with their neighborhoods and their health, and report more depressive symptoms (Andersen and Sandlie 2015). Additionally, the mental health outcomes of Oslo's adolescents also display a socioeconomic gradient - with respondents belonging to less affluent families report having more severe symptoms of depression and lower self-esteem compared to their cohorts with more available resources (Bakken, Sletten, and Frøyland 2016). Although individual-level factors are still the strongest predictors of mental health, a study examining municipal differences has found a small clustering of severe symptoms of depression which cannot be accounted for by individual factors alone (Abebe et al. 2016) - highlighting the need to further explore the effects of school and neighborhood factors on mental health.

In line with this, greenspaces in neighborhoods, through the restorative function they perform, have been found to have the capacity to narrow health disparities which commonly stems from one's socioeconomic position (R. Mitchell and Popham 2008; R. J. Mitchell et al. 2015). In addition, studies have found that deprived subpopulations and other minority groups can potentially benefit the most from having available and accessible, nearby greenspaces (Kabisch, Haase, and Van Den Bosch 2016; Ward Thompson et al. 2012; Maas et al. 2006; Roe, Aspinall, and Thompson 2016; Banay et al. 2017). Furthermore, there is research that suggest greenspaces may affect men and women differently – with women seeing substantial benefits in terms of mental health (van den Bosch et al. 2015) and regulation of stress hormones (Ward Thompson et al. 2012).

To that end, this thesis aims to explore if the availability of greenspaces in the neighborhoods of Oslo are associated with the adolescents' mental health - while considering the interplay of both individual (gender and socioeconomic status) and environmental (neighborhood and school) factors. This area of study could provide valuable insights in the effects of physical environments in predicting adolescent mental health, as well as offer a possible novel approach to mitigating the rising rates of depression among teenage girls in Oslo.

1.1. Neighborhood greenspace in Oslo: is it associated with wealth?

The idea that certain natural features in one's physical environment can promote mental health poses some important questions: are these features equitably distributed, and does it have a socioeconomic gradient?

Research by Andersen and Sandlie (2015) have found that the variation in the living conditions of Oslo's youth has a socio-spatial dimension. Adolescents living in the more affluent, western districts tend have better living conditions characterized by detached housing and private home ownership. They also tend to report higher satisfaction with their neighborhoods and their own health. In contrast, those living in the eastern and central districts are more likely to live in tight apartment blocks and townhouses, and they tend to be less satisfied with their neighborhoods and their own health. However, a causal relationship between living conditions and mental health is hard to establish, and the researchers conclude that the differences in the adolescents' physical environments, though associated with geographic differences, are inexorably linked to their level of family resources and background (ibid).

To establish the viability of conducting this research, an exploratory analysis was performed to examine whether the variation in available greenspace in Oslo's neighborhoods is associated with the average household income and percentage of minority population. The purpose is to examine if richer neighborhoods had more greenspace for its residents, and if minority groups are concentrated in neighborhoods with less greenspace. If these associations existed, it provides support for the notion that unevenness exists in Oslo. *Evenness*, as a dimension of segregation, pertains to the differential distribution of social groups across areal units (Massey and Denton 1988). A distribution is uneven when the percentage of a minority population varies considerably from the minority percentage of the entire city – and are thus over or under-represented in some areas. An uneven distribution of groups is often an indication that segregation exists (Fleury-Bahi and Ndobo 2017).

However, two important caveats are in order. First, it is entirely plausible that spatial inequalities merely coincide with social inequalities, and that spatial unevenness per se should not be treated as concrete evidence of segregation (Cassiers and Kesteloot 2012). The claim of segregation requires a deeper study on many factors; such as temporal and geographic trends, the changes in capital accumulation regimes, effects of xenophobia and racism, and the changing priorities of governing authorities (ibid) – which is already beyond the scope of this thesis. However, if such a coincidence existed, it warrants further exploration especially when it is linked to features in the physical environment that could affect health outcomes. Second, Oslo, as assessed by several international indices and rankings[1] [2] [3], is arguably one the greenest cities in the world whose residents report high satisfaction with the green areas in the city. It almost seems unwarranted to suggest that Oslo's residents may be distributed in a manner that leads to an uneven exposure to the greenspaces of the city. However, that is precisely where this thesis is

[1] Eurostat report on Urban Europe http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_-_statistics_on_cities,_towns_and_suburbs_-_green_cities
[2] Comparison of capital cities around the world using the Green View Index (GVI) http://senseable.mit.edu/treepedia/cities/oslo
[3] European cities comparison using NDVI https://philippgaertner.github.io/2017/10/european-capital-greenness-evaluation/

positioned: in one of the greenest cities in the world, is the variation in greenspace availability *within* the city still associated with individual factors and mental health outcomes.

Using the data provided by the Oslo municipality[4], statistics on average household income and percentage of population based on immigrant background was acquired at a neighborhood (*delbydel*) level. The data were combined with greenspace measures from the Urban EEA project of the Norwegian Institute of Nature Research[5]. The greenspace availability measures used for the analysis are the Normalized Difference Vegetation Index (NDVI), land cover data (grass, forest, water), and contiguous tree canopy cover. These measures are also used in the present thesis and will be further discussed in the proceeding chapters. To account for annual changes that may be due to macroeconomic factors, an average household income from 2011 to 2015 was computed for each neighborhood. A more detailed discussion of the results of this analysis are presented in Appendix 1.

1.2. An uneven Oslo

The exploratory analysis suggests that unevenness exists in Oslo in terms of the distribution of the population based on income, immigrant background, and available greenspace. As predicted, neighborhoods with high average income tend to have more available greenspaces (Figure 1). However, this distribution has an additional dimension: residents who are originally from Norway tend to live in neighborhoods with more greenspace, while those who have origins outside Norway tend to live in less green areas. When dividing immigrant groups based on their region of origin, one finds a more interesting picture of Oslo. Though most immigrants live in neighborhoods with low greenspace availability, western immigrants tend to reside in richer neighborhoods, while most non-western immigrants are clumped together in poorer ones (Figure 2). This shows a very interesting socio-spatial gradient: greener and richer neighborhoods tend to have more Norwegian residents, non-green but rich neighborhoods tend to have more western immigrants, while non-green and poor neighborhoods tend to have more non-western immigrants. The only exception is the South Asian immigrant group which is concentrated in the outskirts of the city, and thus have more greenspace available to them (Figure 3).

[4] Oslo municipality *Statistikkbanken* http://statistikkbanken.oslo.kommune.no/webview/
[5] Urban EEA project website https://nina.no/english

Figure 1: Comparison of Natural Cover and Average Household Income (2011 to 2015) ($r = .305$, $p < .01$)

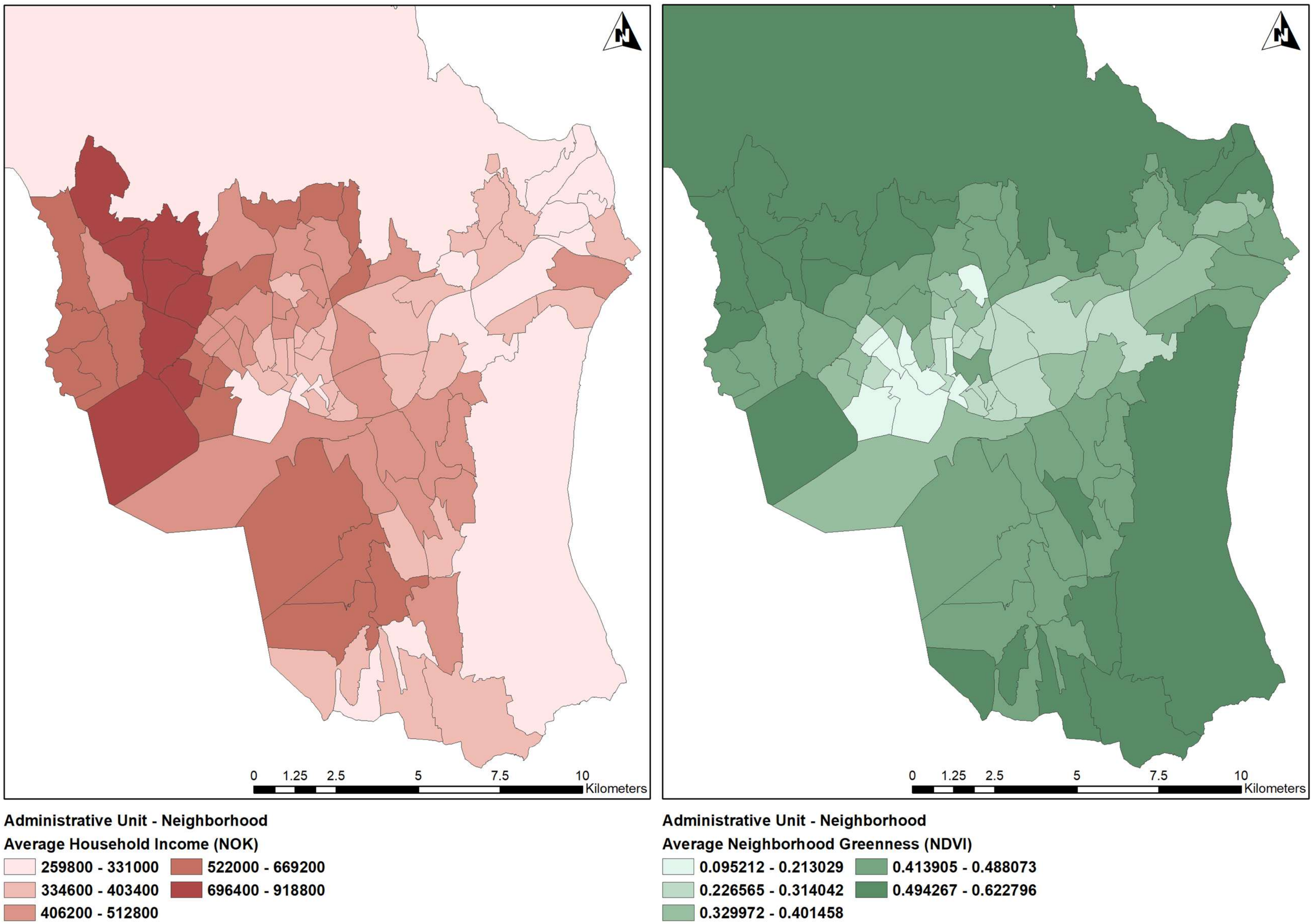


Figure 2: Concentration of immigrant population from Western Countries and Non-western (including Eastern Europe) ($r = .978$, $p < .01$)

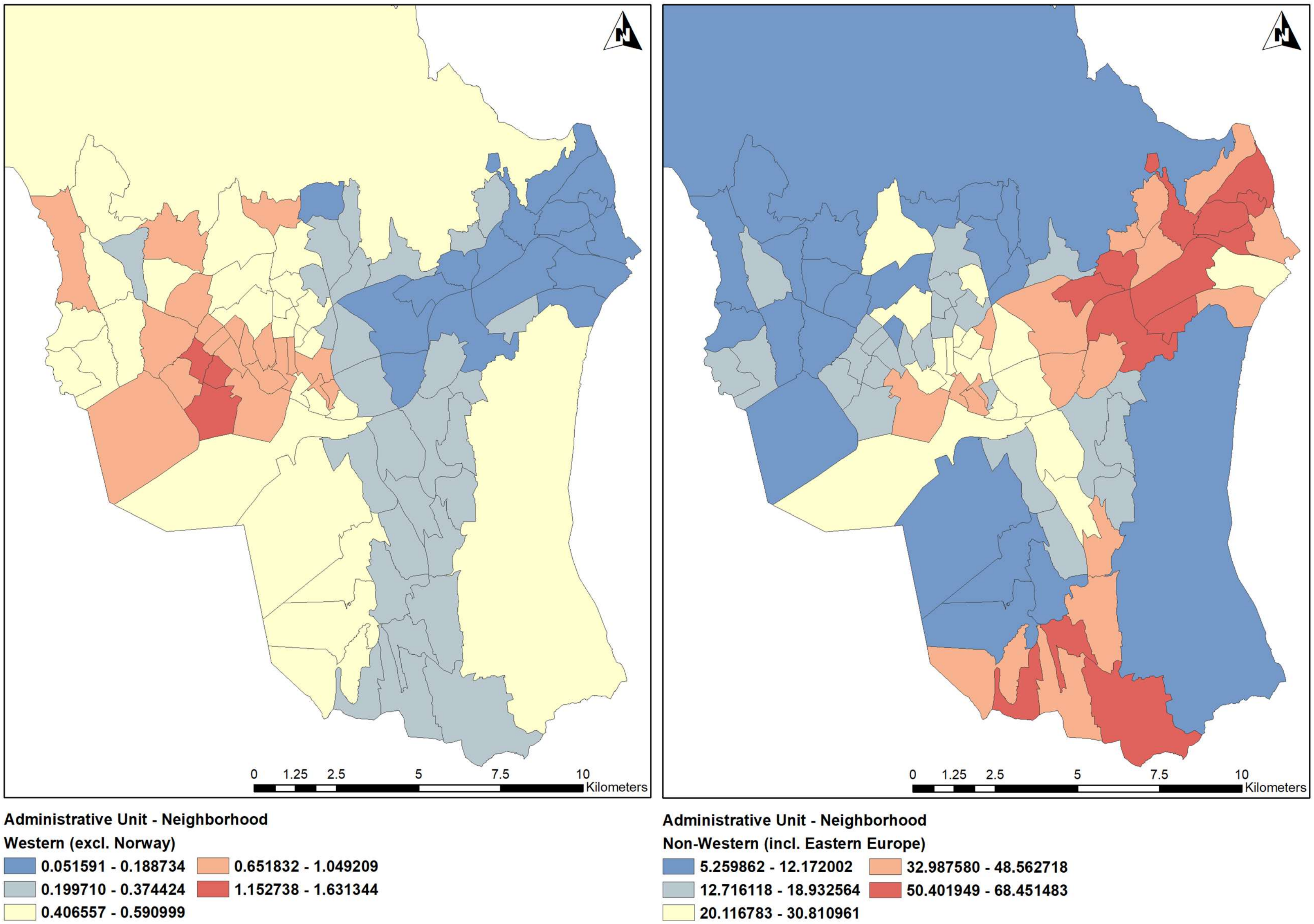
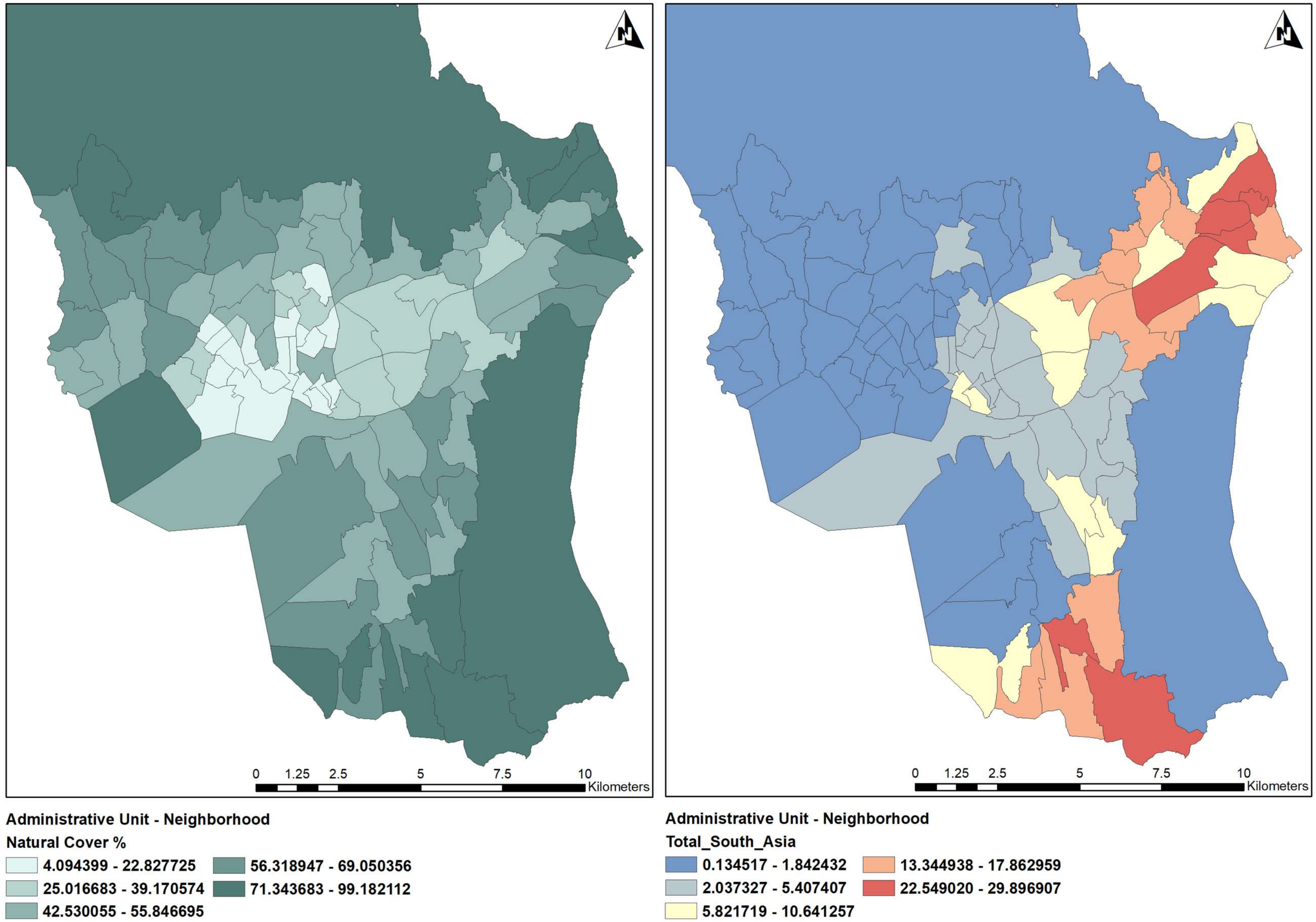


Figure 3: Concentration of population from South Asia and Natural Cover ($r = .283$, $p < .01$)



Considering the wealth of research on greenspace and health, the exploratory analysis offers motivation to investigate if the residential unevenness in Oslo, which is linked to greenspace availability, is associated with the mental health outcomes of the adolescents of the city. However, immigrant background, will not be included in the present thesis because specific questions pertaining to this is not readily available in the dataset used for this study, the Young in Oslo 2015 survey. The survey questionnaire only asks if the respondents, and whether one or both parents, were born outside Norway (Frøyland 2015, 20) – which does not necessarily pertain to their country of origin. The follow-up question, however, pertains to the birthplace of the respondent's parents and it specifically asks which country each parent came from. However, turning the answers into a regional grouping variable would require a good amount of sorting, which is beyond the capacity of a single researcher considering time constraints. Additionally, immigrant background of the respondents, when operationalized as simply being born in or outside Norway, disregards the nuances of being an immigrant based on different global geographic regions – which evidently matters based on the exploratory analysis. This thesis will instead focus on the respondents' family resources and their gender in exploring how individual and environmental satisfaction variables interact with the availability of greenspaces in neighborhoods when predicting mental health outcomes.

In summary, scientific consensus offers support in greenspaces' capacity to promote mental health for urban dwellers (de Vries 2010; Nutsford, Pearson, and Kingham 2013; van den Berg et al. 2015; Gascon et al. 2015). Additionally, greenspaces in neighborhoods have been shown to benefit vulnerable groups and other minority populations, including women, and can potentially mitigate the health inequalities which stem from one's socioeconomic status (South et al. 2015; Roe, Aspinall, and Thompson 2016; Haaland and van den Bosch 2015; R. J. Mitchell et al. 2015). Considering physical environments as a social determinant of health, the results of the exploratory analysis revealed an additional layer of unevenness in Oslo based on available greenspace. The provision of greenspaces in cities therefore ultimately becomes an issue of environmental justice and health equality worthy of further examination (CABE 2010; R. Mitchell and Popham 2008; Hartig 2008)

1.3. Thesis outline

Chapter 2 part 1 will introduce the main definition of *Greenspace* in this thesis. It will also provide a discussion on the various ways greenspace is conceptualized, defined, and why the definition used in the present thesis is the most appropriate one based on the pathway being explored. Part 2 will follow with an overview of the current scientific literature on the health impacts of greenspaces. The model of Hartig et al. (2014) will be used to provide an appropriate summary of the pathways between greenspace and health. Part 3 will introduce the concept of Equigenesis (R. Mitchell and Popham 2008; R. J. Mitchell et al. 2015), as well as present research regarding the moderating role of gender in the effects of greenspace.

Chapter 3 will discuss restorative environments as a conceptual framework. Part 1 will discuss the main theoretical roots of restorative environment research: The Stress Reduction theory (SRT) by Roger Ulrich (1983; Ulrich et al. 1991), and Attention Restoration Theory (ART) by Stephen and Rachel Kaplan (1989). It will also discuss the concept of resources, the antecedent conditions that necessitate its restoration, and how they are viewed in restorative environment research. Part 2 will discuss restorative environment research conducted in Norway and other European settings, with a focus on the physical features that provide the most likelihood for restoration to occur. Part 3 will introduce the indicators of greenspace availability based on the definition used in this thesis.

Chapter 3 will be present the aims and hypotheses of the study.

Chapter 4 will discuss the data and methods of the study. Part 1 will begin by presenting the main datasets used for this study, the Young is Oslo in 2015 survey and geospatial data from the Urban EEA project. Descriptive statistics for the pertinent variables will also be presented. Part 2 will present the statistical tools used, how missing data were dealt with, as well as discussing the reliability and validity of the datasets. The final part will discuss the ethical issues and considerations in doing secondary analysis as it pertains to this study.

Chapter 5 will present the results of the statistical analyses conducted. Part 1 presents the visualizations for the distribution of respondents across the different levels of greenspace availability vis-à-vis *Family Affluence* and *Gender*. This is followed by the results of the bivariate and multivariate analyses (correlation analysis, and hierarchical multiple regression). Part 2 will discuss the results vis-à-vis the hypotheses of the study. Parts 3 and 4 will discuss the limitations of the study and provide suggestion for further research, respectively.

And finally, Chapter 6 will present the conclusions of the present thesis.

2. Greenspace and Health

The important role greenspaces play in promoting well-being for urban dwellers are epitomized in several international agreements to which Norway is one of the signatories. Chief among them are the Parma Declaration[6] and the Sustainable Development Goals (goal 11.7)[7]; both enshrines the commitment to provide every child ample, safe, and accessible greenspace where they can be active and socialize with other children by 2020 and 2030 respectively (WHO 2010; United Nations 2015)

An outcome of both agreements is the World Health Organization's 2016 comprehensive review of literature on the links between urban greenspace and health (Thompson et al. 2016). The publication was primarily intended to provide an overview of current evidence for policy makers and public health specialists interested in greenspace provision in improving population health. In addition, it also proposed standard indicators for measuring greenspace exposure, some of which are used in this thesis, to allow for comparative studies between different populations, and to assist countries in effectively monitoring how they are faring in terms of their commitments to provide universal access to greenspaces (ibid., 21).

The WHO review concludes that the provision of greenspace that encourages people to be active, provide stress recovery, as well as opportunities for social contact, is important in building communities that are resilient to the effects of climate change, as well as reducing the overall demand for healthcare services (ibid., 41).

[6] Parma Declaration document http://www.euro.who.int/en/publications/policy-documents/parma-declaration-on-environment-and-health
[7] Sustainable Development goal 11 https://sustainabledevelopment.un.org/sdg11

This area of study could not be more fitting as human civilization has just reached a monumental milestone in 2014 - when, for the first time in our history, more than half of the global population now lived in cities (the United Nations 2014). It is further projected that by 2050, that number will rise to around 66% (ibid.). With the current trajectory, human settlements will continue to be predominantly urban, and areas specifically dedicated to providing opportunities for contact with nature, and reap the restorative benefits such an experience offers, will be under constant pressure (Thomas 2013; Haaland and van den Bosch 2015). This brings with it an increased risk for mental illness associated with the stresses of urban living (Haaland and van den Bosch 2015; Gidlow et al. 2016; Nieuwenhuijsen et al. 2017).

2.1. What is greenspace?

There is currently no officially recognized definition of greenspace, and it varies depending on the research being conducted and the pathway being studied. As written in the 2016 WHO report "*The definition is nuanced and context-specific"* (Thompson et al. 2016, 3).

Taylor and Hochuli (2017) conducted a systematic review on how the term was defined in literature and found that more than half of the papers did not provide an explicit definition. For the studies that did, six (6) different types were identified. In addition, other terms such as urban greenery, open spaces, natural environments, and urban nature have also been used. This reflects the diversity of the disciplines that use the term "greenspace" (or "green space"), and it also indicates that researchers might have different interpretations of what it is. From the six specified definitions found in the review, two overarching interpretations emerged.

The first is an interpretation of greenspace as nature, or natural areas characterized by an abundance of vegetation and water, and a minimal influence of man-made structures. This definition coincides with what is considered as natural environments and is often expressed in land cover categories that are considered *natural*, as opposed to being *urban*. These could include large nature reserves, forests, coastal areas, and gardens.

The second, and most common interpretation, is simply vegetation found inside urban areas. This interpretation views greenspace as a vegetated variant of open space, and it highlights human planning and effort in placing natural features inside urban settlements.

Additionally, they recommended the use of the one-word compound *greenspace* to cover the different types of definitions. They argued that this avoids confusion, and it denotes that the term had now been lexicalized - included in the vocabulary as a distinct concept, as opposed to simply being a "green space", which can be misinterpreted as being a space that is environment-friendly or merely having the color of green as a defining characteristic (ibid).

Taylor and Hochuli's (ibid) review demonstrated that the interpretations of greenspace in research, though revealing a clear pattern, fails to provide a unifying definition. They concluded that "*rather than suggest a single, prescriptive understanding of greenspace, (we) propose that researchers construct a definition of greenspace for the context of their research that utilizes both qualitative and quantitative aspects"* (ibid).

2.2. An important note about Nature

Before presenting the operative definition of greenspace in this thesis, it is important to emphasize that research on the links between greenspace and health is basically research on the health benefits of *Nature*. Moreover, nature, beyond providing ecosystem services which could ultimately lead to better health, is also something that is experienced (Hartig 1993). This notion is reiterated in Hartig et al. (2014) systematic review where they provide an important discussion on the conceptualization of nature that will underpin the definition of greenspace in this thesis.

Nature, when objectively defined, generally means the phenomena of the physical world; where different objects, features, and process are, and occur, without the intervention of men. This can involve environments considered to be *natural* as it is minimally adulterated by human presence (e.g. the wilderness). However, in most greenspace studies, the kind of nature and natural environments that one can observe and engage with, which subsequently elicits the beneficial health effects, are usually found in built environments. Features such as vegetation and water elements that are merely borrowed from nature, but arranged with human intent and labor, are often what is in consideration in most greenspace research. What's seen as "natural" comes from a framework that is constructed by both the society and its environment co-producing meaning through their sustained interaction with each other (ibid).

Depending on the sociocultural and historical context, encountering natural features can be theoretically sufficient in creating a "nature experience"; which is defined as a subjective perception and evaluation of features that society and its members have come to consider as *of nature* (ibid). As Hartig et al. (2014) review puts it *"although nature has a wide variety of objective referents, it is also experienced subjectively and is effective as a social construction".*

As such, nature can take on many forms (from vegetation to animals), measured using a variety of indicators (average greenness of an area or cartographic natural cover), and engaged with in different activity contexts (from passive viewing of a garden from a window, to a hike on a mountain trail). The ways in which nature has been linked to health also varies considerably between fields of study, populations, and settings (ibid).

This idea is quite pertinent to both the definition used and the pathway being explored in this thesis because earlier research in the restorative capacity of nature have worked with mere representations of nature as socially constructed (Ulrich et al. 1991; R. Kaplan 2001; De Groot and Van Den Born 2003). Additionally, it is important to highlight that many of the greenspace studies in the systematic reviews have worked with heterogenous operationalizations of nature (Hartig et al. 2014; M. Kuo 2015; Markevych et al. 2017). The phrase "*contact with nature*" is common and pragmatic because it can subsume the different aspects of nature being explored - as a feature, place, and experience - with each representing the different pathways to health (Hartig et al. 2014). Depending on the studies, the definition of greenspace in the reviews might pertain to mere vegetation (grass and trees by the road), land cover categories which can be considered as natural, or as actual physical areas (i.e. a park or forest). The theoretical roots of the pathway involve in this thesis operates on the assumption that environments or features we've come to consider as natural, can elicit a response in humans characterized by a lowering of the body's stress responses and allowing for cognitive resources to be replenished – which, in a cumulative manner, can promote well-being (Hartig et al. 2014; Collado et al. 2017).

As will be discussed in the proceeding parts, the definition of greenspace used in this thesis, the measures to indicate its availability, as well as the discussion on the pertinent pathway involved, will be coming from a subjective operationalization of nature.

2.3. Greenspace in the context of this thesis

The operative term in this thesis is "*neighborhood greenspace*" and it has two parts that require operationalization. The first part pertains to one of the official administrative units in Oslo called the "*delbydel"*, which translates to "neighborhood" in English. Data on the respondents' neighborhood of residence is available in the dataset for this thesis and it will be used as the geographic area whose greenspace availability will be measured.

The second part pertains to the greenspace itself, and is defined as space within the neighborhoods of Oslo that is covered by natural features which includes:

- Vegetation of any kind (e.g. grass, shrubs and trees on the side of the road).
- Land cover categories characterized as "natural", which includes grass, forests, and/or bodies of water.
- Contiguous tree canopies of varying sizes.

Since features and categories are quintessentially different, different measures will be used to represent them. These measures are briefly introduced in this part and will be further discussed in detail in the proceeding chapter in relation to their data requirements and applicability as a WHO indicator[8]. It is expected that these measures are highly correlated, but they will be treated as separate greenspace availability measures because doing so offers an opportunity to test if their results vary.

The first kind of greenspace, *vegetation of any kind*, can be quantitatively measured using the Normalize Difference Vegetation Index (NDVI). NDVI measures the health of vegetation, or "greenness", within a defined geographic area (e.g. a neighborhood) by providing a score which ranges from -1 to +1; where higher, positive values indicate an abundance of vegetation, while values closer to zero would indicate barren land or built-up areas. Negative values indicate water or clouds - which has been masked out in the geospatial layer used in this thesis to avoid distorting the data. Each Oslo neighborhood will get an average score of how much greenery is available within its borders. This measure is inclusive and considers all vegetation cover, from

[8] Proposed indicators from the Urban Green Spaces and Health: A review of evidence (Thompson-Ward et al. 2016, 21)

plants and trees on the side of the road, to larger forested areas within the boundaries of the neighborhoods of Oslo. The name of the variable which represents this measure is *Average Neighborhood Greenness.*

The second type of greenspace, *natural land cover categories*, is measured in terms of the percentage of the land area within each neighborhood that is covered by natural cartographic categories. This obviously requires a subjective evaluation on what can be considered *natural*. The land cover data to be used for this thesis has five categories, three of which, grass, forest, and water, will be combined, and the percentage of area they cover inside neighborhood boundaries will indicate how much greenspace is available. This measure will be given the variable name *Natural Cover.*

The third type of greenspace, tree canopies of varying sizes, basically pertains to the leaves and branches of tree patches that form a contiguous block of foliage when viewed from above. The layer to be used in this thesis categorized canopies by the amount of area they cover: from pocket parks (<999 m^2) to large parks (>100000 m^2). These categories will be collapsed together, and like land cover data, the percentage of area inside neighborhoods boundaries covered by the tree canopies will comprise the variable *Tree Canopy Cover*.

The definition in this thesis incorporates both interpretations from Taylor & Hochuli's (2017) review. This definition is appropriate to the pathway being explored, as restoration can occur when there are natural features present in one's living environment, even without one's conscious engagement with greenspaces (Hartig et al. 2014, Collado et al., 2017). The definition is also relevant to the present thesis because it aims to explore the distribution of *nature* across the neighborhoods of Oslo, with the assumption that they make environments more restorative - and to examine if the variation in their availability is associated with mental health outcomes.

However, it is important to note that the definition in this thesis slightly deviates from Taylor & Hochuli's (2017) interpretations. Greenspace as vegetation of any kind inside urban areas operate on the underlying idea that these small elements is a *type* of nature that facilitates restoration. As discussed by Ekkel and de Vries (2017) in their paper evaluating different greenspace accessibility measures, stress reduction and psychological restoration can occur with the mere passive viewing of small natural elements and areas, without having to be in a large natural environment (like in a forest). Furthermore, studies conducted in the Norwegian setting offer support for this notion and have found that different types of vegetation and other natural features are reported to provide the most likelihood for restoration to occur (Bjerke et al. 2006; Nordh et al. 2009; Nordh, Alalouch, and Hartig 2011; Nordh and Østby 2013). Therefore, all the greenspace measures in this thesis, which incorporates all types of vegetation and large swathes of areas mapped under natural cartographic categories, is still viewed as synonymous with nature

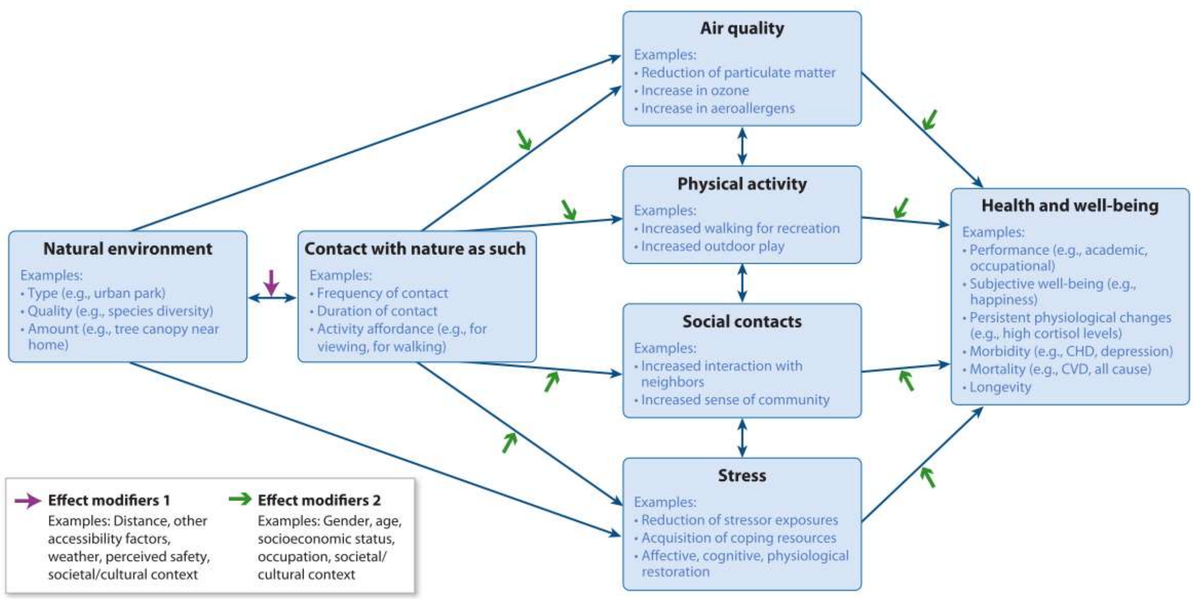
In summary, available *Neighborhood Greenspace* in this thesis will mean *Average Neighborhood Greenness* as measured by NDVI, *Natural Cover* as measured by the percentage of land area in each neighborhood covered by natural categories, and *Tree Canopy Cover* as measured by the amount of area covered by the branches and leaves of Oslo's contiguous tree patches when viewed from above. Each case in the dataset will receive a score for each measure based on their neighborhood of residence - thus indicating how much greenspace is theoretically available to them.

2.4. The different pathways from greenspace to health outcomes

The pathways presented in the WHO 2016 report was largely based on Hartig et al.'s (2014) systematic review of literature. They proposed a model with four interacting pathways that link greenspaces to positive health outcomes. These pathways have served as a robust model in understanding the links between greenspace and health observed in different settings and population groups. However, literature on the links between greenspace and health is massive, and this chapter merely provides a sampling of research which are pertinent to this thesis.

The model by Hartig et al. (2014) has four pathways: *Air Quality, Physical Activity, Social Contacts, and Stress*. (Figure 4). Two of the pathways, *air quality* and *stress,* has a direct link to natural environments. This can be illustrated in a case of having lots of trees and vegetation in one's neighborhood which can provide benefits like improving air quality (Bottalico et al. 2016) and making it more restorative (Beyer et al. 2014). This does not necessarily require conscious engagement with greenspaces. In contrast, encouraging *physical activity* (Takemi Sugiyama and Ward Thompson 2008) and allowing social contact to occur (CABE 2010) requires active engagement, and by themselves can also obviously lead to better health outcomes. Some activities can simultaneously activate more than one pathway – which is often the main justification used for greenspace interventions (WHO 2017b). For example, in a case of a well-maintained neighborhood park frequented by people living nearby, the act of going out to be in the park already involves some type of physical activity (i.e. walking). Natural features present in the park makes the visitation more restorative; and when this involves a pleasant interaction with neighbors who also use the park, increased *social cohesion* (having a sense of shared values and belonging to a community) can also occur.

Figure 4: Pathways from Hartig et al.'s review *Nature and Health* (2014).



Effect modifiers also exist as the availability and accessibility of greenspaces are affected by the demographic characteristics and the social context of the population under study. For example, high levels of vegetation might present issues of safety for certain neighborhoods where it can conceal potential crimes or hide perpetrators (Mancus and Campbell 2018). Conversely, it can also represent a welcome escape from a busy urban life in neighborhoods low crime rates (ibid). Quality of greenspace may also vary depending on the socioeconomic level of the neighborhood, with the potential to exacerbate inequality; such as in the case of unkept gardens in poorer areas that might signal a general sense of despair and abandonment (Garvin, Cannuscio, and Branas 2013; South et al. 2015). However, in terms of current consensus on greenspace interventions, these potential adverse effects can be managed with proper, long-term planning that involves the intended users of the greenspaces (WHO 2017b, 10).

The interacting pathways in the model also highlights the different aspects of nature discussed earlier: as features and elements of the physical environment (i.e. vegetation), as a setting for individual and social activity (i.e. a park), and as an experience (i.e. being *in* nature) (Hartig et al. 2014) – all of which offers different opportunities that can improve health.

In relation to this thesis, the review also highlighted contact with nature can help avoid health problems that can be traced to chronic stress and attention fatigue, and they conclude that there is strong evidence to suggest that being in natural environments can have restorative psychological benefits (ibid).

These pathways are a staple in greenspace research, and in 2016 an expert workshop involving prolific authors in greenspace research collapsed these pathways into three domains which represent the three general functions of greenspaces: *reducing* harm (mitigation), *restoring* capacities (restoration), and *building* capacities (instoration) (Markevych et al. 2017). These three functions cover the biopsychosocial pathways that link greenspace and health, and each pathway is founded on distinct, but complementary, theoretical and practical premises (ibid). The original four pathways are thought to reflect the main concerns of different fields, instead of reflecting greenspace studies as a distinct subject area (ibid). The organizing of the pathways into three domains allows for collaborative work for researchers coming from disparate disciplines. For example, epidemiologists involved in studying the effects of air pollution on health can work with psychologists in understanding the role of air pollution as both a stressor and an environmental agent, and how greenspaces can provide a restorative resource in coping with such a stress (ibid).

Viewing greenspaces in terms of their *functions* establishes the idea that they're presence (or absence) in different areas in a city can lead to health inequality - more so when its distribution is linked to the certain demographic characteristics (e.g. immigrant background) and the general socioeconomic level of an area. This is inevitably linked to environmental justice when lesser greenspace availability in poorer neighborhoods lead to lesser opportunities for restoration for the people living in them, which consequentially contributes to the health disparities observed between the rich and poor (Marmot 2010, 24).

Greenspace research is also clearly intertwined with growing urban populations as different interests compete for much needed space within cities. Although cities have often been associated with development and improved health, urban dwellers also encounter risk factors endemic to the urban environment; such as the depletion of adaptive resources necessary in successfully navigating daily life in cities (Gidlow et al. 2016; Nieuwenhuijsen et al. 2017; van den Bosch and Ode Sang 2017; Stack and Shultis 2013). Stress results when demands outpace the restoration of these resources. As a result, physical and mental health can suffer due to the long-term sequelae of stress brought about by living in cities (Thomas 2013; Collado et al. 2017; van den Bosch and Ode Sang 2017). The wealth of research on greenspaces offer support for their viability as a form of public health intervention which, aside from providing ecosystem services and aesthetic value, can also potentially narrow health gaps and benefit different subpopulation groups.

2.5. Neighborhood greenspace and narrowing health gaps

The first theme this thesis is interested in is how greenspace can narrow health disparities. Within cities, some neighborhoods are apparently more restorative because of the availability of greenspaces that allow for restoration of adaptive resources to occur. To quote Terry Hartig's (2008) commentary on Mitchel and Popham's (2008) research on equigenisis[9] "*as with the distribution of stressors and coping resources, time for restoration and the restorative quality of accessible environments are not equitably distributed*."

There are research offering support for this notion which have found that greenspace accessibility and availability can vary considerably within cities. Often, it is the most affluent members of society who live in areas characterized by better quality and quantity of greenspaces compared to the poorer areas of the city (CABE 2010; Thomas Astell-Burt et al. 2014; Wolch, Byrne, and Newell 2014; Ward Thompson et al. 2016; Hoffimann, Barros, and Ribeiro 2017).

[9] A compound word coined by Richard Mitchel (2008) which means the creation of equality. It combines the prefix equi (equal) and the word genesis (the origin of the formation of something).

In the seminal research of Mitchel & Popham (2008), they were able to show how greenspaces can mitigate the effects of income deprivation on two outcomes: all-cause mortality and circulatory disease. The aim of the research was to see if the commonly observed socioeconomic gradient in health is narrowed for people living in greener areas. They compared respondents on the same level of income deprivation but living across different types of neighborhoods with varying levels of greenspace availability (based on the % of land cover designated as "green space"). As expected, health inequality based on one's socioeconomic status exists – less deprived respondents had better health compared to their more deprived counterparts. But most importantly, they demonstrated that this health inequality was indeed narrower for respondents living in areas with more greenspace. Simply put, if one lived in greener areas, one is likely to have better health compared to someone on the same level income deprivation but living in a less green area. This provided support that greenspaces may have an equigenic property that helps in minimizing the commonly seen health disparities which stems from one's level of income deprivation.

In relation to the health outcomes explored to this thesis, Mitchel et al. (2015) followed up with large-scale study using the European Quality of Life Survey, which involved more than 21,000 respondents across 34 European countries. The results show that the gap in mental well-being caused by one's socioeconomic status was indeed narrower for the group of respondents who reported good access to greenspaces. In addition, they compared access to other neighborhood characteristics and services (such as public transport) and found that only access to greenspaces were associated with narrowing mental health inequality.

Other research exploring this relationship have found that greenspaces can also benefits other minority populations; such as women and children, senior citizens, and those living in disadvantaged communities (Sugiyama et al. 2016; Haaland and van den Bosch 2015). In addition, there are also research showing that lower socioeconomic groups can benefit the most when living in areas with more greenery (Ward Thompson et al. 2016; Roe, Aspinall, and Thompson 2016; Feng and Astell-Burt 2017). More recently, Banay et al.'s (2017) literature review on studies linking greenspace and pregnancy outcomes have found substantial support that neighborhood greenery can improve birth-weight and maternal mental health – and again, the effects were found to be stronger for women belonging to lower socioeconomic groups.

2.6. Research on the gender difference on greenspace and health

The second theme to be explored in this thesis is gender differences in the effects of greenspaces. The WHO report calls for taking gender into account in greenspace research (Thompson et al. 2016, 17) in light of studies that show marked gender differences; such as differences in willingness to engage with greenspace (Currie, Lackova, and Dinnie 2016), gender variation in level of activity in greenspaces (Ode Sang et al. 2016), differential effects in Body Mass Index (BMI) (Sander, Ghosh, and Hodson 2017), as well as finding an association with cardiovascular and respiratory health in men, but not in women (Richardson and Mitchell 2010).

Two pertinent research concerning mental and gender are the research of Bos et al. (2016) and van den Bosch et al (2015).

Bos et al. (2016) looked at how the association between greenspaces and mental health was moderated by age and gender. With a sample of almost five thousand Dutch participants, data on levels of depression, anxiety, and stress, as well as quality of life were analyzed. Results offer support for the hypothesis that there were considerable differences on the effects of greenspace based on gender and age; with women belonging to the youngest and oldest age groups experiencing larger effect sizes. Surprisingly, they found that for the 45 to 54 year-old age group, greenspace was associated with worst mental health. However, they highlight inconsistencies in research, and attributes them to varying sample sizes and differences in the covariates of the studies (e.g. spatial mobility). They concluded that the effects of greenspace were small, and only present for specific age and gender groups (ibid).

In the second study, van den Bosch et al. (2015) looked at the different kinds of greenspaces, specifically different types of recreational nature qualities, and their effects on mental health. Longitudinal data was obtained based on a public health survey of around twenty-five thousand Swedish participants, with a goal to measure differences in mental health associated with moving to a different neighborhood with a different amount and type of nature quality. Based on extensive research, five different qualities of recreational nature were used in the study; Serene, Wild, Lush, Spacious, and Culture. Results indicate that only Serene nature (described as a place of solemnity) was significantly associated with better mental health, and this association was only found in women. They concluded that having access to recreational nature of a certain quality may prevent mental issues in women.

These studies offer support for gender's moderating role in the association between greenspace and health. Additionally, it highlights that different types of greenspace quality might yield different results and should thus be incorporated in future greenspace studies.

2.7. Chapter summary

Greenspaces, through various, interacting pathways, can improve well-being for urban populations. The restorative function they perform have been shown to improve mental health and narrow health disparities which stems from one's socioeconomic status. Furthermore, there are gender differences in the ways greenspace affect well-being, with some evidence offering support that it could benefit women more in terms of improving mental health. Understanding greenspace's capacity to narrow health gaps, as well as acknowledging how this could vary depending on one's gender, could have profound implications on health equality and provide a deeper understanding of how greenspaces, as a form public health intervention, could benefit an increasingly urban global population.

3. Restorative Environments as a conceptual framework

This chapter will discuss what restorative environments are and the two foundational theories the area of study is built on. It will also discuss the kinds of resources that need restoration, the precedent conditions that require them to be restored, and how greenspaces allow for restoration to occur. It will also present different indicators for available *neighborhood greenspace* that will be used in this thesis and discuss how it relates to the operative definition.

3.1. Stress and Restoration

Before discussing restorative environments, it is important to discuss what restoration is in the context of health promotion. Health, as defined by the WHO is "*a state of complete physical, social, and mental well-being, and not merely the absence of disease and infirmity"* (WHO

2006). This definition is multidimensional and positive, and it emphasizes the presence (as opposed to the absence) of factors that promote health. One of these factors is the availability of adaptive resources (physical, social, and psychological) that promote optimal functioning (Collado et al. 2017).

The process of wading through daily life in cities require the use of these resources – and they can be depleted depending on the rate they are used, and the rate that they are restored. Restoration is therefore defined as the process of renewal and recovery of resources that are used in the ongoing effort to navigate our environment (Hartig 2004). Stress ensues when the demands for resources overwhelm the process of restoration. Stress then becomes chronic when this imbalance persists, and opportunities for complete restoration are few and far in between (ibid). In turn, chronic stress, extended over long periods of time, can lead to a variety of mental health issues (Zandstra et al. 2015; Benoit et al. 2016; Jackson, Knight, and Rafferty 2010; Thomas 2013).

A specific area of study concerning restoration is research on *restorative environments*, or environments that can promote, and not merely permit, restoration of adaptive resources (Hartig 2004). Although natural environments are not the only ones that allow for restoration to occur, most research in restorative environments are founded on the exploration of nature's salutogenic properties (Collado et al. 2017).

3.2. Human Settlements and Nature

Though the term greenspace is a fairly recent addition in the academic lexicon, promoting health by providing dedicated areas in cities where nature dominates have been around since the 1800s. Renowned American landscape architect Frederick Law Olmsted, responsible for the Central Park in New York and other national parks in the United States, have already prioritized the creation of areas specifically designed for people to have contact with nature. Intuitively, it was widely acknowledged that these areas had the capacity to restore the cognitive resources necessary in adapting to the increasingly urban settlements people were migrating into. (Kaplan 1995).

The accumulation of literature on nature's restorative qualities appear to offer support for the Biophilia Hypothesis of Edward Wilson (1984); which postulates that human beings have an innate tendency to prefer natural environments and connect with other life forms due to our evolutionary roots; and that doing so can have positive psychological effects (Wilson 1984 quoted from Thompson et al. 2016). Kuo (2016) provides a related example of how zoos in the past simply caged animals in similar, artificial environments devoid of features found of their natural habitat. Although all their biological needs were met, people were baffled that the animals still lived shorter lives compared to their wild counterparts - even when living in the wild meant exposure to predators and other natural hazards like starvation and disease. Zoos then started to experiment and found that mimicking the animals' natural habitat was effective in improving life expectancy and minimizing psychological distress. Today, it is generally acknowledged that environment enrichment for animals in captivity dramatically improves their wellbeing (Carlstead and Shepherdson 2017). This idea is reiterated in the psychoevolutionary theories in greenspace literature which posits that our history as a specie predispose us to favor natural environments and landscapes because they have features that signal necessary resources needed for survival (Ulrich 1983; Kaplan and Kaplan 1989; S. Kaplan 1995).

From this perspective, navigating artificial, urban environments may pose additional demands in one's cognitive resources, and these resources need restoration from time to time. Greenspace found in urban environments, may it be in a form of a park or vegetation along the road, can promote restoration because it they create a "naturalness" reminiscent of humanity's historical habitats, and is thus instinctively appealing. In a cumulative manner, it is theorized that the restoration facilitated by greenspaces can improve health and well-being for people living nearby.

3.3. Foundational Theories of Restorative Environments

Research on the restorative capacity of greenspaces have often worked with two prominent theories that regard natural environments as having the capacity to facilitate health: the Stress Reduction Theory (SRT) by Ulrich (1983; Ulrich et al. 1991) and the Attention Restoration Theory (ART) by the Kaplans (Kapland & Kaplan 1989; Kaplan 1995). Both theories posit that contact with nature in one's immediate surroundings can promote health by allowing recovery from stress and the restoration of attentional resources that have been depleted in the process of satisfying environmental demands. Each theory has an antecedent condition that necessitates restoration, with each having their own restoration process.

SRT postulates that people's initial response to environmental cues are automatic and instinctual in nature. This involves a quick evaluation of environmental characteristics that could be interpreted as either threatening, or appealing - and are thus characterized by negative or positive emotions, and a heightened or relaxed physiological response (Ulrich et al. 1991). This is the antecedent condition in SRT; the autonomic response to environmental cues lead to a sympathetic "flight or fight" activation that can deplete resources. Restorative environments, therefore, trigger an opposite parasympathetic response in humans that facilitates stress reduction. In this theory, natural environments signal necessary resources needed for the survival of our ancestors, and the stress reducing response in modern humans is an evolutionary throwback (ibid). There is ample research that provide support for this theory which are based on several objective measures; including concentrations of certain hormones in the bloodstream related to the body's stress response (Ulrich et al. 1991; Ward Thompson et al. 2012; Gidlow et al. 2016).

In contrast, ART suggests that humans have two types of attention: directed attention which requires focus (e.g. completing a mental task), and *fascination* which is effortless (e.g. staring blankly at a natural scenery) (Kaplan and Kaplan 1989). ART operates on the assumption that cognitive resources are constantly used to focus on most everyday tasks by blocking out distractions that compete for one's attention. Prolonged focus is the antecedent condition which depletes cognitive resources needed to function effectively - which consequentially necessitates restoration. Due to the complexity of natural patterns and processes, human attention can be captured in an effortless manner, and thus allow for cognitive resources one would otherwise use for focusing to be replenished (Kaplan 1995). Fascination is considered the primary quality of restoration in ART; the other three are compatibility, extent, and being away. It is considered that these qualities are neither a part of a person or the environment but refers to the transaction between them (Collado et al. 2017). For example, in compatibility, a congruence between what a person aims to do in the environment, and environmental qualities that support this aim, are necessary for restoration to occur. A classic example demonstrating this is working as a lumberjack, where being in the forest might not necessarily be restorative if it is considered as a place of work. Extent refers to the coherence of structure an environment has, as well as the having enough scope for involvement. The last quality, being away, refers to having physical and/or psychological distance from everyday concerns – which can understandably be quite restorative. These qualities will not be explored in this thesis as there are no data which can be used to measure them. There is, however, an underlying assumption that greenspaces in neighborhoods can elicit the primary quality *fascination*, which is considered necessary in inducing restoration.

Both theories, though operating in different antecedent conditions are ultimately intertwined, and an integrative framework was proposed (Kaplan 1995). Today, both are generally acknowledged as the theoretical foundations of restorative environment research (Hartig 2004; van den Berg et al. 2015; M. Kuo 2015; Collado et al. 2017; Markevych et al. 2017).

Studies based on these theories conducted in various settings have yielded quite consistent results: from perceived neighborhood greenness leading to better mental health outcomes (Sugiyama et al. 2008; Dadvand et al. 2016; Gascon et al. 2015), to improved mental health after moving to a "greener" neighborhood (Alcock et al. 2014). As for bigger natural areas, research done on the traditional Japanese practice of *Shinrin-yoko,* or forest bathing, have shown that being in natural areas lowers stress, reduces negative mood, decrease blood glucose levels for diabetic patients, and better cardiovascular health (Tsunetsugu, Park, and Miyazaki 2010; Q. Li et al. 2011; Mao et al. 2017; Hansen, Jones, and Tocchini 2017). When comparing urban and rural inhabitants, there is also research that show people who grew up in urban areas are more likely to experience chronic stress compared to those who grew up in rural areas (Steinheuser et al. 2014). Within cities, health disparities can also be observed between people who have access to local gardens versus those who don't - with those who have access substantially experiencing less stress (Ward Thompson et al. 2016). Additionally, the depletion of attentional resources has also been linked to aggression because it is seen as a product of one's inability to control antisocial impulses as demonstrated by Kuo and Sullivan's (2001b, 2001a) research comparing people living in similar social housing units, differentiated only by variations in outside greenery.

As with other greenspace research, there is an underlying assumption in this thesis that the availability of natural features in neighborhoods allow for restoration to occur. SRT and ART predicts that an environment that is relatively more *natural* would provide more chances for restoration versus an environment that is more artificial, or *urban*. There have been several studies conducted in the Norwegian setting that offer support for this assumption - most of which are conducted in the field of landscape architecture and aimed at investigating features in the environment that provide the most likelihood for restoration to occur.

In one study conducted in Oslo specifically focused on park designs, park components were assessed based on their likelihood to facilitate restoration (Nordh and Østby 2013). Participants in the study were presented with 74 pictures of small urban parks and were asked to enumerate park components they believe would be restorative. The presence of grass, flowers/plants, and water features were the most commonly mentioned and highly rated features linked to restoration. A similar study assessing different types of surface cover using pictures of parks sampled from different Scandinavian cities found that the most predictive qualities for restoration were percentage of ground surface covered by grass, and the amount of viewable vegetation (trees and bushes), as well as park size (Nordh et al. 2009). Another study also found that when choosing between different parks to sit and relax in, people preferred parks with more vegetation (Nordh, Alalouch, and Hartig 2011).

Based on these and other studies on restorative environments, having more neighborhood greenspace is theorized to provide more opportunities for restoration for people living within the area, and in a cumulative manner, can lead to improved mental health outcomes.

3.4. Conceptualization of Greenspace exposure

The WHO report discusses three ways of conceptualizing exposure to greenspace: *Usage, Accessibility,* and *Availability* (Thompson et al. 2016, 21). The data used for this study only allows for measuring greenspace exposure in terms of availability due to ethical and privacy considerations. The exact addresses of the respondents in the Youth in Oslo survey are not available, therefore measuring proximity will not be possible (i.e. how far the nearest greenspace from one's residence). Instead, availability measures, like measuring average greenness in the neighborhood they live in, will be used. However, it would seem prudent to briefly discuss the other types of conceptualization to highlight how availability measures might be more pertinent to the pathway being explored.

Measuring *Usage* often requires more specific monitoring as it indicates actual usage of greenspaces. It can include measures such as official count of park visitations by monitoring authorities, GPS tracking of individuals, and self-reported greenspace visitation. This data is currently not available for the Young in Oslo survey, and thus cannot be used in this study.

Accessibility measures considers how much of a population has access to a specific greenspace area (e.g. a park); it usually considers other characteristics such as access points, openness for public use (e.g. park ownership, with/without entrance fees), and size of the greenspace in focus. The key point of accessibility measures is measuring proximity, and different international standards have been proposed. A common one, as discussed in the WHO report (ibid, 25) is the accessibility standard for the United Kingdom which specifies *access* as having a greenspace area that is at least 2 hectares in size and has a maximum linear distance of 300 meters from one's residence - which roughly equates to a 5-minute walk. As seen in this example, access points and ownership of the greenspace is not specified.

Another way to measure accessibility is to measure it in terms of the percentage of the population living within a specified buffer (or layers of buffers) around a greenspace of a certain size. This is the measure being proposed by the WHO to allow for cross-country comparisons. Statistics Norway (SSB) uses accessibility measures in this fashion as well, but instead uses the terms access to *"recreational areas"* and *"areas for recreational walking"*[10] . These areas are categorized based on their sizes. *Recreational areas* are those that are larger than 5 acres, while *areas for recreational walking*, which includes sports fields, are for smaller areas accessible for public use. SSB also considers *safe access* in their measure, which involves certain parameters such as not having to cross a street with heavy traffic to get to these areas. Data on greenspace accessibility for the different neighborhoods in Oslo is not freely available, therefore it will not be used in this study.

[10] SSB overview on access to *recreational area* and *areas for recreational walking.* The website also elaborates on the definition of these terms https://www.ssb.no/en/arealrek

Availability measures are the most generally defined and it often only quantifies greenspace within a geographic area without consideration for ownership, public access, and size. The three indicators for greenspace availability proposed by the WHO 2016 review are the Normalized Difference Vegetation Index (NDVI), percentage of land area categorized as greenspaces, and measures of street trees and streetscape greenery (i.e. canopy cover). These measures are available for Oslo, and availability scores for each neighborhood can be acquired by simply drawing the neighborhood boundaries and using a geographic information system (GIS) software to extract neighborhood level data. This will be further explained in the proceeding part.

Measure of availability and accessibility are not always mutually exclusive and what sets them apart is how they are conceptualized based on the research being conducted and the pathway being studied. For instance, NDVI can be used as a measure of both accessibility and availability; availability in terms of measuring how much greenness is within a defined administrative boundary, and accessibility when it measures the percentage of greenness within a certain distance around a given point, like a school or house.

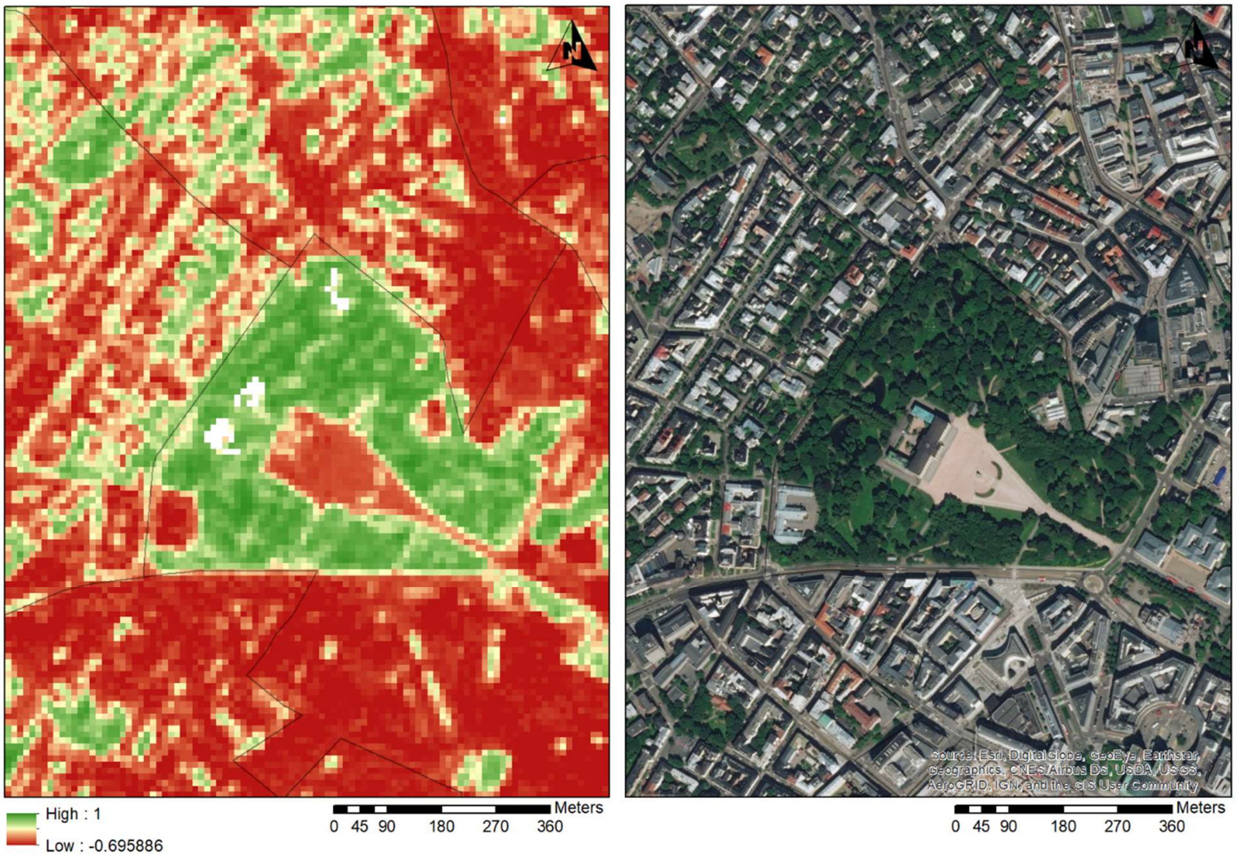
3.5. Measures for Neighborhood Greenspace

The measures to indicate neighborhood greenspace availability in this thesis will be discussed in relation to the data requirements and applicability as WHO greenspace indicators. Important parameters to be discussed include resolution and source of data material.

3.5.1. Average Neighborhood Greenness (NDVI)

The first indicators of greenspace availability used in this thesis is the Normalized Difference Vegetation Index (NDVI). NDVI measures vegetation density within a defined geographic area based on satellite imagery. This multispectral image is further analyzed through a GIS software, to extract the data needed for this thesis. NDVI is one of the most common measures used to indicate greenspace research because of its ease of applicability (Thompson et al. 2016, 24). NDVI basically measures the spectral reflectance of plants to gauge their health and condition, and yields a value ranging from -1 to +1; with higher positive values indicating a higher density of plant cover, and negative values indicating water or snow which is customarily "masked out"[11]. Figure 5 shows a comparison between NDVI data view and a satellite image of the same area.

Figure 5: Comparison between NDVI data view and satellite image of the palace park (*Slottsparken*)



The NDVI layer[12] for this thesis is readily available for download, with no additional processing needed (i.e. masking out water and snow). This data comes in a form of a preprocessed multispectral satellite image of Oslo taken by the Sentinel-2 mission satellites in August 22, 2015 - which provides a rough estimate of the available greenery in Oslo at the height of its bloom season (just before the end of summer). NDVI was derived from bands 4 and 8 of the satellite image, and has a resolution of 10m, which means every square pixel in the image roughly corresponds to a 10x10 m^2 area on the ground. The minimum requirement as a WHO indicator is a resolution of 30m, which means that the data used in this thesis can be considered

[11] "Measuring Vegetation (NDVI & EVI): Feature Articles." NASA. Accessed January 14, 2018. https://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php.
[12] NDVI for Oslo 2015 by Megan Nowel, http://urban.nina.no/layers/geonode%3A_2015_ndvi_masked_wgs84

more refined. Note that the time the image was taken came after the Youth in Oslo survey was conducted. The NDVI scores are only treated as an approximation of the amount of greenspace available in the neighborhoods at the height of the greenest season of the year. Taking the image on the time the survey was administered, which is the winter season, would not be representative of how much available greenspace an area truly has. It is also rare for studies to use aggregated NDVI images taken from various times of the year since the production of such data would require technical expertise in remote sensing (Markevych et al. 2017). In terms of being used in this research, the resolution can be considered enough in comparison to the WHO requirement.

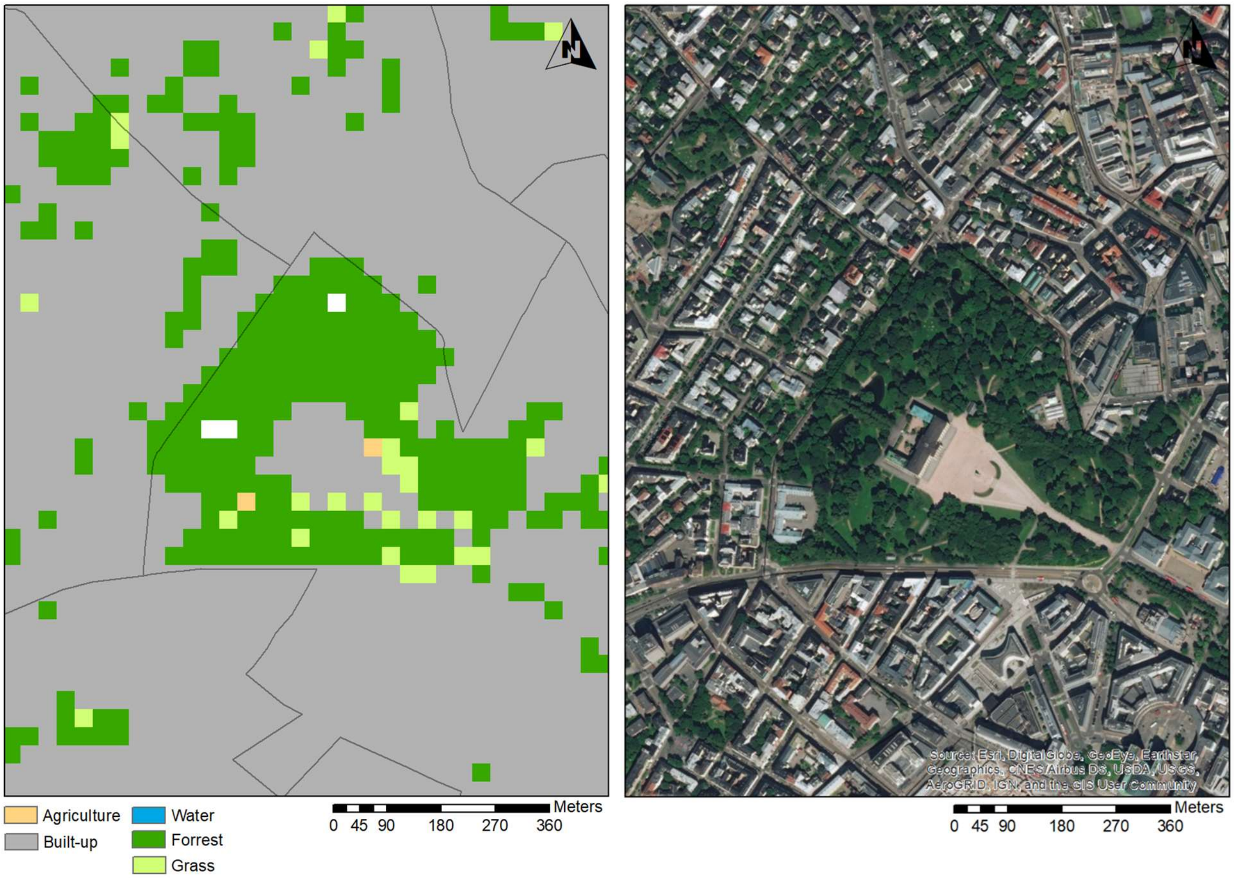
NDVI is a common approach to investigating the pathway being explored because it accounts for the total level of vegetation within an area. It is an alternative conceptualization that doesn't merely measure distance to an official park area in which data on actual usage may not be available.   NDVI could also be the most pragmatic measure for neighborhood greenspace, with research showing that it highly correlates with expert ratings on environmental greenness, and can easily be used for replication and comparative studies (Rhew et al. 2011). NDVI has been used in several research that examined neighborhood greenery and health. (Gascon et al. 2015) found out that greater exposure to neighborhood greenery lead to improve physical and mental health. Beyer et al. (2014) found that higher NDVI scores of neighborhoods is associated with lower levels of anxiety, depression, and stress.

3.5.1. Natural Cover

Natural cover represents cartographic land cover categories that can be considered natural, includes a variety of categories such as grass, forest, and even bodies of water. The layer for this thesis has five categories: Agriculture, Built-up, Grass, Water, and Forest. As a greenspace measure for this thesis, the last three categories will be combined to represent the amount of *natural* cover available within neighborhoods.   The data layer[13] used for this thesis was taken from 2015 and has a resolution of 30m, which means that a square pixel in the image roughly corresponds to a 30x30 m^2 on the ground. Figure 4 shows a comparison of this layer and satellite imagery, which is slightly more granulated compared to the NDVI data view.

[13] Land Cover map for Oslo 2015 by Zofie Zimburova http://urban.nina.no/layers/geonode%3Alc2015#more

Figure 6: Comparison between land cover data view & satellite image of the palace park (*Slottsparken*)



Note that the category *Water* is included. There is a separate area of study which regards water as a different kind of nature; *bluespaces,* which is distinct from greenspaces, and is characterized by water instead of vegetation. However, this thesis will not delve into a theoretical discussion regarding bluespaces, suffice to say that some greenspace studies and reviews have included bluespaces in their analysis (Thompson et al. 2016; Huynh et al. 2013; MacKerron and Mourato 2013). For this thesis, all types of natural surface cover, which includes grass and forests (greenspace) and water (bluespace) will be combined to measure the percentage of a neighborhood's total land area which can be considered natural.

For cross-country comparison, the layer used here may not be applicable as a WHO indicator because each country uses different kinds of cartographic categories, which could be inappropriate to compare (Thompson et al. 2016, 23). However, since this thesis is not comparing land cover data across different countries, this data is applicable as a generic greenspace measure within the conceptual framework being used. Furthermore, the categories in this measure, as well as those that are excluded, are clearly defined, thereby allowing for other research to verify/replicate this study using the same land cover categories. In a pragmatic sense, since the definition of greenspace used is synonymous with nature, the inclusion of both of vegetation and water categories is justified.

3.5.2. Tree Canopy Cover

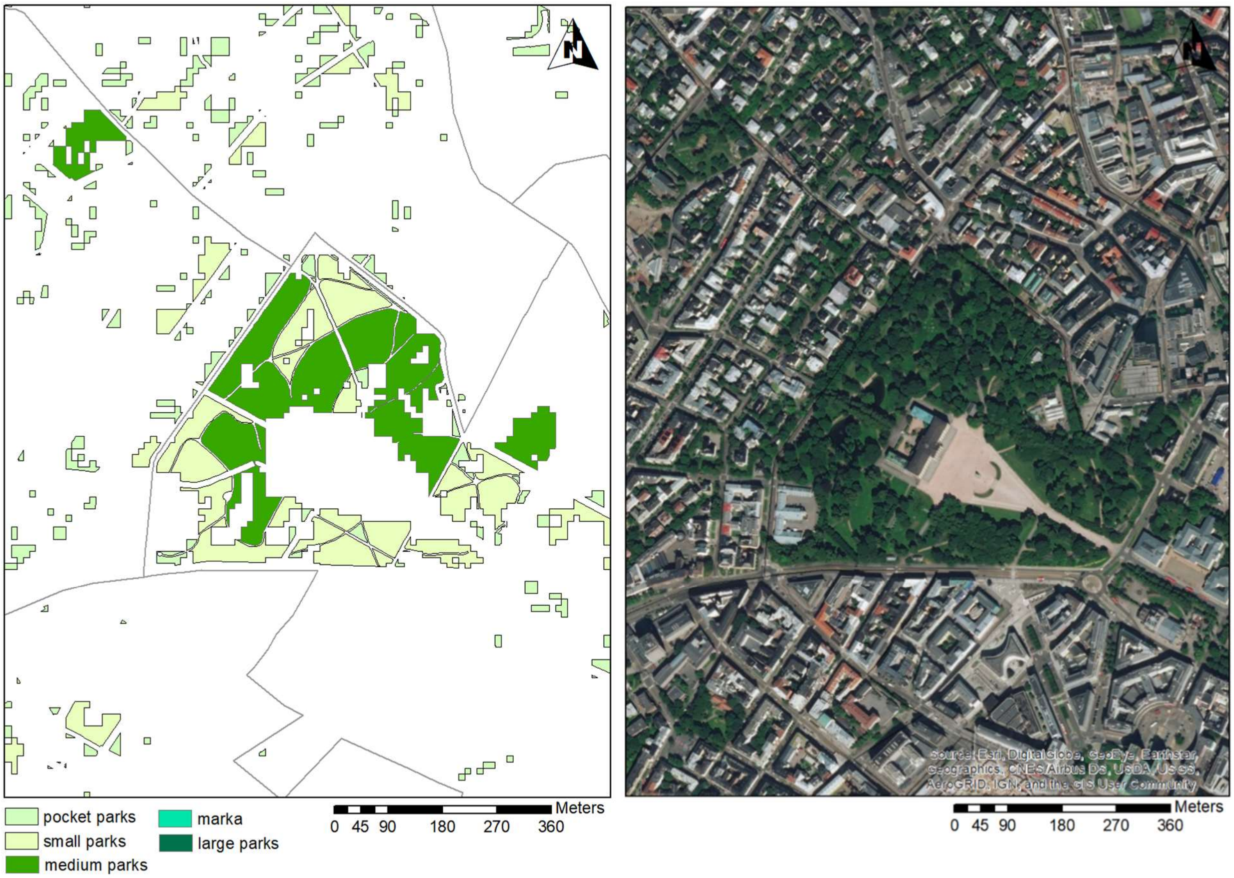
Tree canopy cover refers to the amount of area covered by the crown of contiguous tree patches when viewed from above. The definition of greenspace in this thesis includes tree canopies because of the assumption that when these features are present in the environment, restoration is more likely to occur. The data layer[14] used for this thesis maps the area covered by the tree canopies (originally called "park areas" by the author), which is classified based on sizes: <999 m2: pocket park; 1000-4999 m2: small park; 5000-99999 m2: medium park; >100000 m2: large park.

The data layer was produced using satellite imagery from August 22, 2015, with a spatial resolution of 10m. Like the NDVI data, the tree canopies were mapped after the administration of the Young in Oslo Survey. This is to acquire a closer approximation of the amount of area covered by tree canopies because certain species of trees shed leaves during winter. Figure 5 shows the comparison between the tree canopy data layer and satellite imagery.

This layer does not necessarily fit the indicators for greenspace availability proposed by the WHO (Thompson et al. 2016, 24) because the report mainly emphasizes the availability of trees (or tree canopies) that can be viewed at the street level (street tress and streetscape greenery). However, as an indicator for greenspace availability, the layer suffices as a measure of a natural feature that is theorized to have restorative qualities. In a pragmatic sense, having lots of trees can make neighborhoods appear more natural, and is thus consistent with the conceptual framework used in this thesis.

[14] Tree canopy areas of Oslo by Megan Nowell http://urban.nina.no/layers/geonode%3Acanopy_class_25832#more

Figure 7: Comparison between tree canopy data view & satellite image of the palace park (*Slottsparken*)



3.6. Chapter summary:

Urban living, due to our evolutionary roots, demand cognitive resources to navigate. To successfully adapt, opportunities for periodic restoration are needed to allow these resources to be replenished. The more natural features present in the environment, the more restorative potential it has. Greenspaces and other forms of natural surface cover in neighborhoods increase the likelihood for restoration to occur. This is what underpins the main assumption for this thesis, and it presupposes that residents in neighborhoods with more greenspace are more likely to have better mental health.

Based on the theoretical foundations of the pathway in focus, neighborhood greenspace in this thesis is synonymous to *nature* within neighborhoods, which can be quantifiably measured by looking at the level of vegetation present within a given area, the amount of area covered by cartographic categories commonly assessed as “natural” and measuring how much tree canopy is present in the area.

This thesis will focus on availability measures and uses a broader definition of greenspace, which includes all forms of nature that can be found in neighborhoods; which includes mere vegetation, gardens, parks, and tree canopies. This follows the idea that these natural elements in neighborhoods can illicit the positive psychophysiological effects seen in studies on the restoration pathway. Utilizing an inclusive definition, as opposed to stricter one which only includes officially recognized parks and forests, would be appropriate as mere visual contact with natural elements can be sufficient in eliciting restoration. In studying the pathway and health outcome this study is interested in, availability measures (how much nature is present), as opposed to accessibility (distance to nearby park one can visit), is considered the most appropriate.

4. Aim and Hypotheses of the study

This thesis primarily aims to examine the association between neighborhood greenspace and mental health in the senior high school (*videregående*) students of Oslo. Specifically, it will explore if the availability of greenspaces in the neighborhoods they live in is associated with their reported depressive and anxiety symptoms. The goal is to understand the interplay between the adolescent’s gender, their satisfaction with their school and neighborhood, and level of family resources in predicting mental health outcomes, while considering the amount of greenspace available in their immediate environment.

The secondary aim for this thesis is to explore the distribution of respondents based on neighborhood greenspace measures to see if it has a socioeconomic gradient. This is based on the exploratory analysis conducted for this thesis presented in the introduction where higher neighborhood greenspace availability was associated with higher levels average household income. The visualization for the secondary aim will be presented in the results section to provide an overview of how the respondents of the Young in Oslo 2015 survey are distributed based on the greenspace measures, and to explore if the variables associated with the greenspace measures follows a certain pattern.

4.1. Operational definitions:

As discussed in the early chapters, *neighborhood greenspace* is defined as vegetation, natural cover, and tree canopy found inside the neighborhoods of Oslo – each represents a measure of greenspace availability expressed as *Average Neighborhood Greenness, Natural Cover,* and *Tree Canopy Cover.*

The term *Neighborhood* in this research pertains to the official administrative unit called a *delbydel*. The study locale, the Oslo municipality, has 3 different levels of administrative divisions. The largest are the districts (*bydeler*), which Oslo has 15, in addition to the central area (*Sentrum*) and the forest area surrounding the city (*Marka*). The districts of Oslo are further divided into 94 suburban units (*delbyler*), which will be the neighborhoods referred to in this thesis. Each district has approximately 5-9 neighborhoods each. This research will be using the neighborhood boundaries from the old administrative map that was in place during the Young in Oslo survey in 2015. Four (4) suburban units were since divided in 2017, leading to the current total of 98 suburbs (Oslo Municipality, ND.).

The smallest administrative division is the basic unit (*grunnkrets*), which collective form the neighborhoods. The combination of some basic units into neighborhoods is quite pertinent to this thesis as the Ungdata questionnaire asks for residential information that did not necessarily fit the recognized administrative boundaries. In the Young in Oslo 2015 electronic questionnaire, the first two questions pertain to the district and neighborhoods the respondents lived in respectively. After providing district information, the follow-up question offered additional choices of neighborhoods within the respondents' home district. Some of the choices for the neighborhoods were combinations of basic units that locals collectively recognize as a distinct neighborhood, but cuts across different officially recognized neighborhood boundaries. Some choices were also a combination of basic units within a larger neighborhood, but with the whole neighborhood being treated as a separate choice.

To overcome this issue, data for all three indicators of greenspace were extracted on both the basic unit and neighborhood levels. The choices for neighborhoods that perfectly matched recognized administrative divisions retained their greenspace scores. Those that did not, received new scores that were the average of the basic units that constituted them. Additionally, before acquiring the data set, 9 neighborhoods were combined with adjacent suburbs due to the small number of respondents in them. This was done by the author of the Young in Oslo 2015 report prior to the release of the dataset for the present thesis based on how it was mapped for the survey.

The map layer used to define the neighborhood boundaries was downloaded from Geonorge[15] in a form of a SOSI[16] file format which was subsequently converted to allow for manipulation in Arcmap (ver. 10.5.1). The map layer required additional processing because it only contained district and basic unit boundaries, so the neighborhoods had to be constructed by combining the basic units that comprised them as recognized by the Oslo municipality prior to the 2017 change. A table for the combinations of basic units per neighborhood, as well as other information on the manipulations done in drawing the neighborhood boundaries in this study is provided as a supporting document (Appendix 2).

The term *environmental satisfaction* in this thesis pertains to the subjective evaluation of the respondents of the two environments they are likely to be exposed to on a regular basis: their school and neighborhood. *Neighborhood Satisfaction* and *School Satisfaction* are the variables that represent this term, and they are measured with a dichotomy of being satisfied or dissatisfied.

Finally, *Family Affluence* refers to the respondents' socioeconomic status; but instead of using income as a measure, it utilizes the availability of family resources (i.e. number of cars, having an own room, number of vacations in the past year, and number of computers in the house).

These measures, and how they are used in the statistical analyses are further discussed in the proceeding parts.

[15] Geonorge website where free map layers on Norway's administrative boundaries can be download https://goo.gl/22vxQf
[16] SOSI file description https://sosicon.espenandersen.no/

4.2. Hypotheses of the study

The hypotheses of this study will be tested through multiple regression analysis, which is a correlational method that examines the strength and direction of the association between variables. In addition, environmental satisfaction variables, specifically school and neighborhood satisfaction, will be included in the models to examine how they interact with greenspace availability. This thesis has three hypotheses, which reflects the different aims presented in the preceding part. Hypothesis 1 pertains to the distribution of respondents as guided by the exploratory analysis. Hypothesis 2 pertains to the association of greenspace measures with the pertinent variables of the study. And finally, hypothesis 3 pertains to the gender difference this study aims to explore.

Hypothesis 1: Based on the exploratory analysis conducted for this thesis, it is expected that more affluent respondents tend to live in greener areas. It is expected that:

a. Neighborhood greenspace is positively correlated with Family Affluence.

Hypothesis 2: Based on the literature on greenspace and restorative environments presented in chapters 2 and 3, it is expected that higher greenspace availability leads to better mental health and higher environmental satisfaction. Specifically:

a. Neighborhood greenspace availability is positively correlated with Neighborhood satisfaction.
b. Neighborhood greenspace availability is negatively correlated with Depressed Mood and Anxiety.

Hypothesis 3: the final hypothesis of the study pertains to the dynamics of the study variables in relation to gender differences based on the literature presented in Chapter 2. It is therefore expected that there will be a substantial difference in the standardized coefficients (β) of the predictor variables in the models comparing male and female respondents.

The hypotheses for this thesis involves all three measures of neighborhood greenspace availability, and support is provided when there is a significant association found in *at least one* of greenspace measures.

4.3. Data and Methods

This study is cross-sectional in design and will combine existing data from the Young in Oslo 2015 survey and data from the Urban Ecosystem Accounting for Urban Ecosystems project (Urban-EEA) to investigate if there is an association between *Depressed mood* and *Anxiety,* and the amount of available greenspace in the neighborhoods of Oslo. This part will discuss the main sources of the data in this thesis, how they are used in the statistical analyses, as well as presenting the descriptive statistics for the pertinent variables.

4.3.1. Young in Oslo

The primary data material for this study is from the Young in Oslo 2015 survey (*Ung i Oslo* 2015) conducted by the Norwegian Institute for Research on Childhood, Welfare and Aging (NOVA) in partnership with the Regional Drug and Alcohol Competence Centers (KoRus). It utilizes the Ungdata questionnaire which is administered to the different municipalities in Norway; with the national Ungdata database being composed of data from Oslo and the other participating municipalities. (Frøyland 2015, 8).

The Young in Oslo 2015 survey is one of the largest ever conducted in Norway and it maps the different aspects in the lives of the adolescents in the city (Andersen and Bakken 2015). It utilizes a purposive sampling design aimed at acquiring a representative sample of the junior and senior high school populations of Oslo. Themes covered include relationships, school, extracurricular activities, drug use and criminality, health, participation in sports, politics and society, and other demographic information (ibid).

The Young in Oslo 2015 survey has a large sample size (N=24,163) which roughly represents around 70% of Oslo's teenagers, and allows for sufficient generalizations from the data. The response rate was 86% for the junior high school (*ungdomstrinnet*), and 72% for senior high school (*videregående*). Fifty-eight (58) junior high schools and thirty (30) senior high schools participated in the survey, which was conducted between January to March of 2015 (Andersen and Bakken 2015, 7). This thesis will use the dataset for the 2015 survey for the senior high school level.

4.3.2. Urban-EEA project

The Urban-EEA project is managed by the Norwegian Institute of Nature Research (NINA) in collaboration with the Oslo School of Architecture and Design (AHO) and Statistics Norway (Barton 2017). It is aimed at providing vital information on land use for municipal authorities and policy makers by mapping Oslo's urban green infrastructure, and the cultural ecosystem services they provide. The Urban-EEA project has been producing different maps and layers of the Oslo region[17], which can be easily accessed by other researchers interested in using geospatial data. All the neighborhood greenspace measures used in this thesis will be coming from geospatial data provided freely by the project. The indicators are downloaded as a form of a map layer that can be viewed and manipulated using a Geographic Information System (GIS) software, such as the one used in this thesis, Arcmap ver. 10.5.1.

4.4. Measures

The measure for this study required data sets from two disparate disciplines to be combined to answer the research questions. The background variables and outcome measures are taken from the Young in Oslo Survey 2015, while neighborhood greenspace data is taken from Urban EEA project. Each case in the Young in Oslo data set will be given a score for how much greenspace in available in their area of residence, and this score will then be treated as an independent variable which represents the amount of greenspace available to them. The total number of observations in the final Youth in Oslo dataset is 10135. Missing data and how it is treated is discussed in section 5.5. *Family Affluence* scores are available for 10043 of the respondents, while 9959 provided an answer to the item pertaining to their gender.

Descriptive statistics on all the variables for this thesis will be presented to provide an overview of the of the respondents for this study. This will include looking at the prevalence of *Depressive mood* and *Anxiety*, and their proportions in terms of *Gender,* and *Family Affluence*; as well as descriptive statistics for the measures of neighborhood greenspace: *Average Neighborhood Greenness* (NDVI), *Natural Cover, Tree Canopy Cover*.

[17] Urban EEA project website http://urban.nina.no/

4.4.1. Background Variables

Since the Ungadata surveys are meant to be anonymous, the questionnaire historically had a limited number of background variables to avoid identification of the respondents through what is called a "backway identification" (Frøyland 2015, 18). Except for the larger municipalities, most surveys were done in 2010-2013 almost did not use any background variables. However, the changes introduced in 2014 allowed for more background information to be gathered, with a requirement that the items should not compromise the anonymity of the respondents (ibid). Two background variables from the Ungdata questionnaire pertinent to this research are *Gender* and *Family Affluence*.

4.4.1.1. Gender

Gender is a dichotomous variable and corresponds to an item in the questionnaire that asks: "*Are you a boy or a girl?*". Possible responses to the question comes in a form of two options: "1 – Boy", and "2 – Girl". This dichotomous variable was recoded to fit the binary coding of 1-0, where "Boy" was recoded as 0, while "Girl" was recoded as 1. Table 1 shows that for senior high school respondents of the Young in Oslo 2015, 51.8% identified as female, and around 48.2% identified as male.

Table 1: Descriptive statistics for the variable *Gender*

Gender	**N**	**%**
Male	4799	48.2
Female	5160	51.8
Total	9959	100

4.4.1.2. Family Affluence

Family Affluence is the measure which represent the adolescents' s socioeconomic status (SES). Measuring the adolescent SES can be quite difficult because having a personal source of income is not the norm for the age group and asking about their parents' income could yield inaccurate data. To overcome this issue, family resources are measured instead. The variable for this study is composed of 4 items which was taken from the *Family Affluence Scale II* (FAS II), originally developed for the WHO research on socioeconomic differences and its impact on health

(Frøyland 2015, 23). The four FAS II items which measures family resources were included in the Ungdata questionnaire in 2013 (ibid). The variable in this thesis represents the total score of the four items.

The questions corresponding to the adolescents' *Family Affluence* include:

I. "*Does your family have a car?*" followed by the response options "1 - No", "2 – Yes, one", and "Yes – two or more".

II. *"Do you have your own bedroom?"* followed by the response options "1 – Yes", and "2 – No".

III. *"How many times have you travelled somewhere on holiday with your family over the past year?"* followed by the response options "1 – Never", "2 – Once", "3 – Twice", and "4 – more than twice".

IV. *"How many computers does your family have?"* followed by the response options "1 – None", "2 – One", "3 – Two", and "4 – More than two".

The total scores for the four items were standardized, with the final *Family Affluence* score ranging from 0-3, with 0 indicating a low level of family resources, while 3 indicates an abundance (Bakken, Sletten, and Frøyland 2016).

Table 2 shows the average *Family Affluence* score is 2.10, with the median slightly higher at 2.27. On an average, level of *Family Affluence* in the respondents are in a medium to high range. The difference between the mean and median suggests that the distribution is negatively skewed. Table 3 presents the descriptive statistics of *Family Affluence* vis-à-vis Gender.

Table 2: Descriptive statistics for the variable *Family Affluence*

	N	**Mean**	**Median**	**SD**
Family Affluence	10043	2.1	2.27	0.66

Table 3: Descriptive statistics for *Family Affluence* by *Gender*

	N	**Mean**	**Median**	**SD**
Family Affluence: Male	4744	2.1	2.3	0.67
Family Affluence: Female	5128	2.11	2.25	0.63

4.4.2. Independent Variables

The two variables used to measure environmental satisfaction are part of a 6-item scale in the Ungadata questionnaire that pertains to the adolescents' level of life satisfaction (Frøyland 2015, 24). The items ask for the respondents' subjective evaluation of various aspects of their lives; which includes their satisfaction with their parents, friends, school, local community, health, and appearance. The origins of the items are unknown, and only the individual items pertaining to school and local community satisfaction are included in this thesis.

4.4.2.1. Neighborhood Satisfaction

This variable provides a subjective measure of the adolescents' perception of their neighborhood quality. The question corresponding to the *Neighborhood Satisfaction* asks, "*How happy are you with various aspects of your life: the local community where you live*".

The response options follow a Likert-scale format with "1 -Very unhappy", "2 - Slightly unhappy", "3 - Neither happy nor unhappy", "4 - Quite happy" or "5 – Very happy".

The answer was recoded into a dummy variable with responses from 1-3 recoded as 0, and responses 4 and 5 recoded as 1. This reflects a dichotomy between being dissatisfied (0) or satisfied (1) with their neighborhood.

Table 4: Descriptive statistics for *Neighborhood Satisfaction* by *Gender*

Neighborhood Satisfaction	**Dissatisfied with their neighborhood**		**Satisfied with their neighborhood**	
	N	**%**	**N**	**%**
Male	1060	26.70%	2906	73.30%
Female	1537	33.20%	3089	66.80%

Descriptive statistics show that a majority of respondents from both *Genders* are satisfied with their neighborhoods; 73.3 % for males, and 66.8% for females.

4.4.2.2. School Satisfaction

As with the previous variable, *School Satisfaction* provides a subjective measure of the adolescents' perception of their school quality. The question corresponding to this variable asks, "*How happy are you with various aspects of your life: the school you go to*".

The response options follow a Likert-scale format with "1 -Very unhappy", "2 - Slightly unhappy", "3 - Neither happy nor unhappy", "4 - Quite happy" or "5 – Very happy".

The answer was recoded into a dummy variable with responses from 1-3 recoded as 0, and responses 4 and 5 recoded as 1. This reflects a dichotomy between being dissatisfied (0) or satisfied (1) with their school.

As with the previous environmental satisfaction variable, there is also a high level of satisfaction among respondents of both genders when it comes to their school environment; 73.3% for males, and 71.8% for females.

Table 5: Descriptive statistics for *School Satisfaction* by *Gender*

School Satisfaction	**Dissatisfied with their school**		**Satisfied with their school**	
	N	**%**	**N**	**%**
Male	1060	26.70%	2911	73.30%
Female	1309	28.20%	3326	71.80%

4.4.2.3. Neighborhood Greenspace

The independent variable which reflects the availability of greenspace was constructed by combining four types of data layers: three separate greenspace availability indicators (*Average Neighborhood greenness, Natural Cover,* and *Tree Canopy Cover*) and a layer that marks the neighborhood boundaries. Neighborhood boundaries combined with the greenspace measures yields the values for the variable (see previous chapter). All the variables pertaining to neighborhood greenspace availability is continuous and will be used directly in the statistical analyses.

Average Neighborhood Greenness is measured using NDVI and yields a value from -1 to +1. *Natural Cover* ranges from 0% to 100%, which reflects the amount of area covered by natural cartographic categories. *Tree Canopy Cover* is similar natural cover in terms of being measured form a 0%-100% scale, the only difference is that it reflects how much of an area is covered by contiguous tree canopies when viewed from above.

Table 4 presents the descriptive statistics for the *Neighborhood Greenspace* measures. *Average Neighborhood Greenness* for the neighborhoods in Oslo is .432, which is very close to the NDVI score the entire Oslo region received from a study comparing European capital greenness[18]. *Natural Cover* is 52.72%, suggesting that on an average, Oslo's neighborhoods have a fair amount of nature within its borders. *Tree Canopy Cover* is also quite high at 37.69%, which means that when viewed from above, that is how much of the land area of Oslo is covered by its trees and the leaves of their branches.

Table 6: Descriptive statistics for *Neighborhood Greenspace*

Measures of Neighborhood Greenspace	**Mean**	**SD**	**N**
Average Neighborhood Greenness (-1 to +1)	0.432	0.089	10135
Natural Cover (1% to 100%)	52.72	18.06	10135
Tree Canopy Cover (1% to 100%)	37.69	17.12	10135

4.4.3. Dependent Variables

The dependent variables for this study are *Depressed mood* and *Anxiety*. These outcome measures will be used to illuminate the possible effects of neighborhood greenspace on what is commonly used in literature as *mental health* outcomes. This section discusses the items used in the composite measure as well as their origins in relation to their use in the Young in Oslo survey.

[18] Oslo's NDVI .436 score in the comparison of major capital cities by Philipp Gaartner. https://philippgaertner.github.io/2017/10/european-capital-greenness-evaluation/

4.4.3.1. Depressed Mood

Depressed mood is a composite measure of a 6-item scale that was designed to assess mental health. The items pertain to depression symptoms and were adapted from two well-known scales, the Hopkins Symptom Checklist and Depressive Mood Inventory (Frøyland 2015, 40). The scales are part of a much larger set of questions, but earlier studies have shown that the shorter version also have high validity (Frøyland 2015, 41). Two additional items were initially included in an earlier version of the scale but were subsequently dropped after the Ungdata 2010 surveys showed high levels of depressive mood in the respondents. It was suspected to be a questionnaire effect, hence the removal of the said items (ibid).

The question corresponding to the depressive mood asks, "*during the past week, have you been affected by any of the following issues:*", which was followed by items representing depressive symptoms:

- *I. Felt that everything is a struggle*
- *II. Had sleep problems*
- *III. Felt unhappy, sad or depressed*
- *IV. Felt hopelessness about the future*
- *V. Felt stiff or tense*
- *VI. worried to much about things*

Response options follow a Likert-scale format with "1 – Not been affected at all", "2 – Not been affected much", "3-Been affected quite a lot", "4-Been affected a great deal".

Adding the response to the six items yields a score for *Depressed mood* which ranges from 6 (no symptoms) to 24 (heavily affected). These scores were then standardized and transformed to a 0-3 continuous scale, with 0 having no symptoms to 3 for severe. The standardized scores are used in all statistical analyses for this thesis.

As a composite measure, the scores for *Depressed Mood* ranges from 0-3, with higher scores denoting an increase in the severity of symptoms. Table 5 shows that means score for the male sample is .96, and 1.44 for females. This indicates that on an average, male respondents have lower rates of depression compared to females, which is consistent with previous research conducted using data from the Young in Oslo surveys. (Table 5).

Table 7: Descriptive statistics for *Depressed Mood* and individual item components

Depressed Mood	**Mean**	**Median**	**SD**	**N**
Male	0.96	0.83	0.73	4799
Female	1.44	1.33	0.8	5160

4.4.3.2. Anxiety

Like the *Depressive mood* outcome variable, *Anxiety* is also a composite of a 4-item scale used to assess mental health (Frøyland 2015, 42). The items on this measure are originally a part of the *Depressive mood* scale and were only added as an additional measure in 2013. After the revision in autumn 2013, the questionnaire battery was moved to the basic module (ibid). No additional information is provided on the *Anxiety* measure. Although it has the same origins as the *Depressive mood* measure, it will be treated as a separate outcome variable for this thesis.

The question corresponding to *Anxiety* asks: ""*during the past week, have you been affected by any of the following issues:*", which was followed by items representing anxiety symptoms:

- *I. Suddenly felt scare for no reason*
- *II. Felt constant fear or anxiety*
- *III. Felt exhausted or dizzy*
- *IV. Been nervous or felt uneasy*
- *V. Been easily moved to tears*
- *VI. Tended to blame yourself for things*

Response options follow a Likert-scale format with "1 – Not been affected at all", "2 – Not been affected much", "3-Been affected quite a lot", "4-Been affected a great deal". As with *Depressed Mood* these scores were standardized and transformed to a 0-3 continuous scale, with 0 having no symptoms to 3 for severe. For the statistical analyses in this thesis, only the standardized scores are used.

Just like the first outcome variable, the *Anxiety* is also a composite measure with scores ranging from 0-3, with higher scores denoting an increase in the severity of symptoms. Average score for Anxiety in males is .36, suggesting that the male respondents in the survey report few symptoms of Anxiety. Female respondents on the other hand have an average score of .91, almost 3 times higher than males. This is again consistent with the results of previous Ungdata reports on the psychological health complaints of Norwegian teenagers (Andersen and Bakken, 2015).

Table 8: Descriptive statistics for *Anxiety* and individual item components.

Anxiety	**Mean**	**Median**	**SD**	**N**
Male	0.36	0.17	0.54	4799
Female	0.91	0.67	0.76	5160

4.5. Data Analysis

Data preparation and analysis for this thesis was mainly done in IBM SPSS Statistics version 24 for Windows. However, the construction of the final data set required preliminary sorting in a spreadsheet program.

4.5.1. Bivariate Analysis: Pearson's correlation

Bivariate analysis involves investigating if a linear relationship, or an association, exists between two variables. The Bivariate analysis to be utilized in this study is the Pearson's correlation, which is used in determining the strength of a linear relationship between two continuous variables. If there is a relationship between the variables of the study, a variation in one variable would mean a coinciding change in the other variable.

Correlation analysis is conducted for this thesis based on two reasons. First, to provide an overview of how the outcomes variables, *Depressed mood* and *Anxiety*, are related to the each of the independent variables in the study. Second, it will provide results needed in answering the first three hypotheses: whether available neighborhood greenspace is associated with the other independent variables, and the outcome variables depressed mood and anxiety in the respondents.

4.5.1. Multivariate: Hierarchical Multiple Regression

Hierarchical multiple regression will be utilized in this study to check for the additional predictive value of the measures for neighborhood greenspace, while controlling for the effects of background variables and environmental satisfaction. Since this thesis will be looking at difference based on gender, the file will be split with *Gender* as the grouping variable. The first model will include the background variables *Family Affluence*, followed by the two environmental satisfaction measures *Neighborhood* and *School Satisfaction* respectively. Each succeeding model will involve the addition of a different neighborhood greenspace measure to see how each measure predicts the outcome variables of the study. By comparing different regression models, while controlling for *Family Affluence, Neighborhood* and *School Satisfaction*, the effects of each neighborhood greenspace measures on the respondents' depressed mood and anxiety symptoms scores can be assessed.

4.6. Missing data

The Young in Oslo 2015 dataset used in this study has undergone a standardized procedure for data cleaning prior to its use in this thesis. This involves the elimination of unserious responses through indicators designed to identify them. These indicators detect combinations of answers to different questions which would be improbable, and in cases where more than two indicators of unserious responses are detected, the entire case is eliminated from the data file (Frøyland 2015). For the neighborhood greenspace measures, all cases were given a score based on neighborhood of residence. Respondents with no answers are excluded from the analysis.

The rates of missing data for the study are: *Gender* (1.7%), *Family Affluence* (0.9%), *Neighborhood Satisfaction* (14%), *School Satisfaction* (13.8%), *Depressed Mood* (11.3%), *Anxiety* (12.3%). In total, missing data for this thesis was relatively low all variables and is not a cause for immediate concern.

4.7. Study Quality

The data set used in the study is of very high quality as assed by the Norwegian Social Research (NOVA). Documentation of the reports are highly specific, freely available, and employ strict methodological standards (Bakken, Sletten, and Frøyland 2016; NSD 2016).

External validity is high, and the sampling was purposive; which was generally targeted at all senior high school students. There is high response rate of 72%, and with most of the schools in Oslo participating, the sample is considered representative of Oslo's senior high school population. Internal validity pertaining the composite measures were not assessed for this study. However, they have been in previous studies[19], local[20] and national[21] reports, as well as theses at the masters and PhD levels[22].

In terms of the measures used to indicate neighborhood greenspace availability, quality was discussed in Chapter 2 in the relation to the standards prescribed by WHO (Thompson et al. 2016, 21). However, there is a concern in terms of the concept of a "neighborhood" in the context of this thesis. Using official administrative boundaries could be considered an unsophisticated measure of one's immediate environment. There is a growing consensus that immediate surrounding areas represented by small circular buffers (i.e. 100m-250m) around a person's residence is more pertinent when investigating the restorative functions of greenspaces (Amoly et al. 2015). However, for obvious ethical reasons, exact address is not available for the respondents of the current study. This, and other limitations, will be further discussed in the final chapter.

4.8. Ethical Considerations

The present thesis is a secondary analysis of an existing data from the Young in Oslo survey, which has followed a process ensuring high ethical standards (NSD 2016). The data set is already anonymized prior to its acquisition. The administration of the electronic survey involves informed consent, where the participants and their parents were told about pertinent details of the study, as well as what participation entails (Andersen and Bakken 2015). The respondents were duly informed of their rights as participants, including the right to not participate in the survey or skip any questions they did not feel comfortable answering.

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[19] List of books and publications using Ungdata http://www.ungdata.no/Forskning/Publikasjoner/Boeker-og-artikler
[20] List of local reports using Ungdata http://www.ungdata.no/Forskning/Publikasjoner/Lokale-rapporter
[21] List of National reports using Ungdata http://www.ungdata.no/Forskning/Publikasjoner/Nasjonale-rapporter
[22] List of master theses and PhD dissertations using Ungdata http://www.ungdata.no/Forskning/Publikasjoner/Master-og-ph.d.-oppgaver

Since the survey entails answering questions of a sensitive nature (i.e. bullying, use of drugs, mental health complaints), after-care is an immediate concern in case it would trigger negative emotions or feelings in the participants. In such an event, students had the option to undergo debriefing with the school nurse or anonymously through a toll-free Red Cross hotline (Andersen and Bakken, 2015).

5. Results

This chapter presents the results of the statistical analyses conducted using the variables of the study. The first part presents the visualizations for how the respondents are distributed across varying levels of greenspace availability vis-à-vis *Family Affluence* and *Gender.* The second part presents the results of the bivariate analyses of the variables pairwise. The final part will present the results of the hierarchical multiple regression conducted to test the hypotheses of the study.

5.1. Exploration of respondents' distribution based on greenspace availability

As an extension of the exploratory data analysis (Appendix 1), the respondents were divided into four equal groups based on the three measures of *Neighborhood Greenspace* availability. The groups follow an increasing degree of availability which ranges from Lowest to Highest. Likewise, respondents were also divided into 4 equal groups based on *Family Affluence*. A visualization of the distribution of respondents based on their *Family Affluence* across the different levels of greenspace availability is presented in the proceeding parts.

5.1.1. Greenspace vis-à-vis *Family Affluence*

As seen in figure 8, the socioeconomic gradient observed in the distribution of the respondents show a clear pattern. The gradient exists but there appears to be a reversal when moving from lower to higher average neighborhood greenness. For the lower groups, the socioeconomic gradient is very pronounced, and only 16% of the most affluent respondents are in the low greenspace group, versus 32.3% and 30.4% for the higher-mid and high greenspace groups respectively.

The decision to treat each neighborhood greenspace measures separately appears to be justified, as there is a marked difference between the distribution based on different measures of greenspace availability. As seen in figure 9, the pattern in the socioeconomic gradient for the *Natural Cover* groups is not similar compared to the first measure. Though for the lowest natural cover group, the pattern is similar, a shift in the distribution can already be seen on the lower-mid group. For the high natural cover group, the pattern is the same compared with the low natural cover group – suggesting that unlike vegetation measures, the respondents seem to be more equitably distributed when natural land cover categories are used. Figures 8 to 10 show that when comparing the distribution across the three greenspace availability measures, *Average Neighborhood Greenness* is closer to *Tree Canopy Cover*, which is somewhat expected considering they both measure vegetated cover, with the former measuring all types of vegetation, and the latter measuring only trees.

Figure 8: Distribution of respondents based on Average Neighborhood Greenness

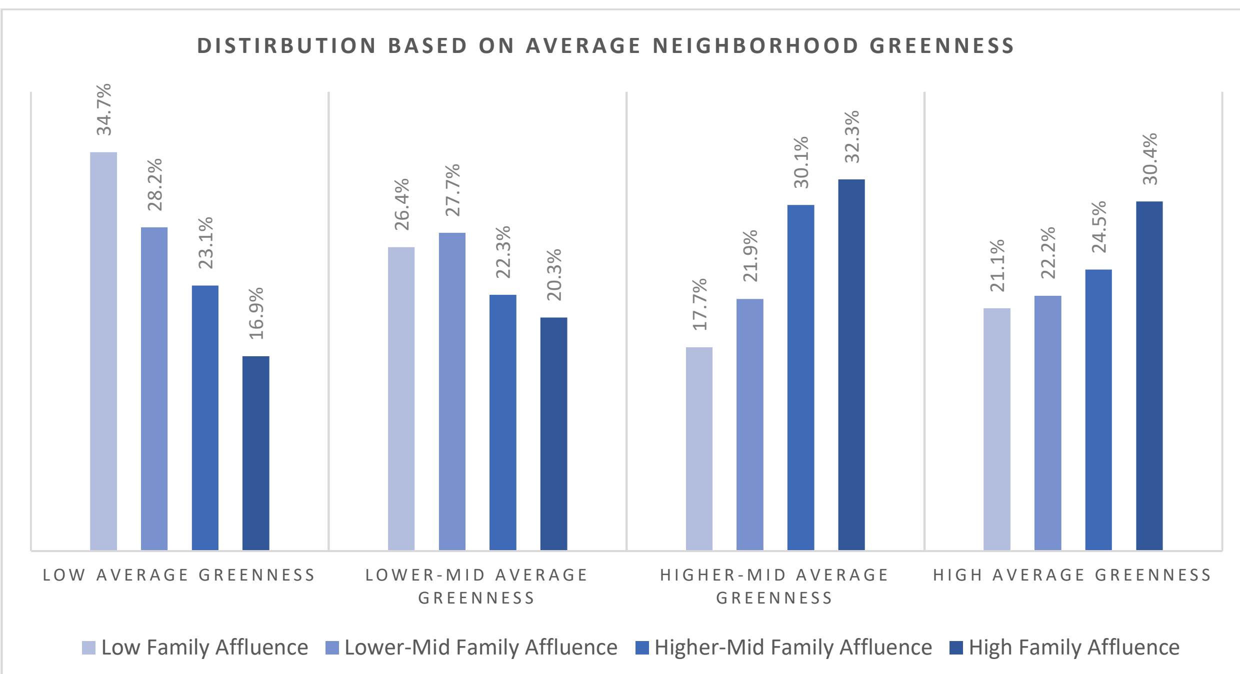


Figure 9: Distribution of respondents based on Natural Cover

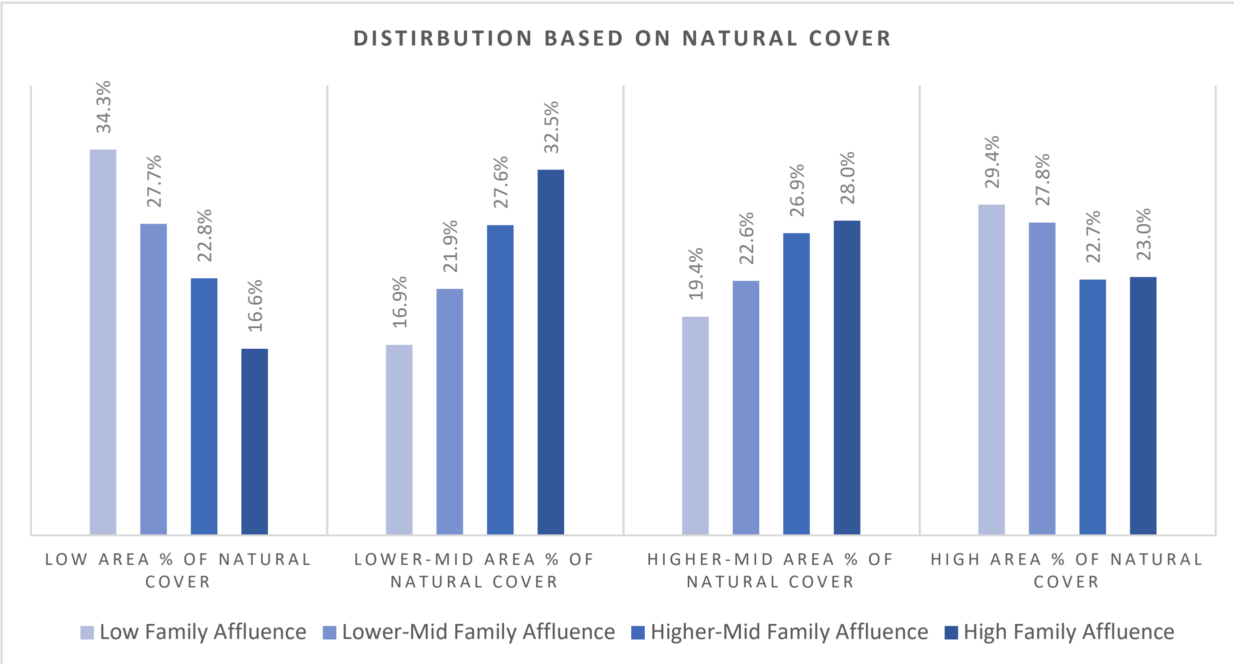
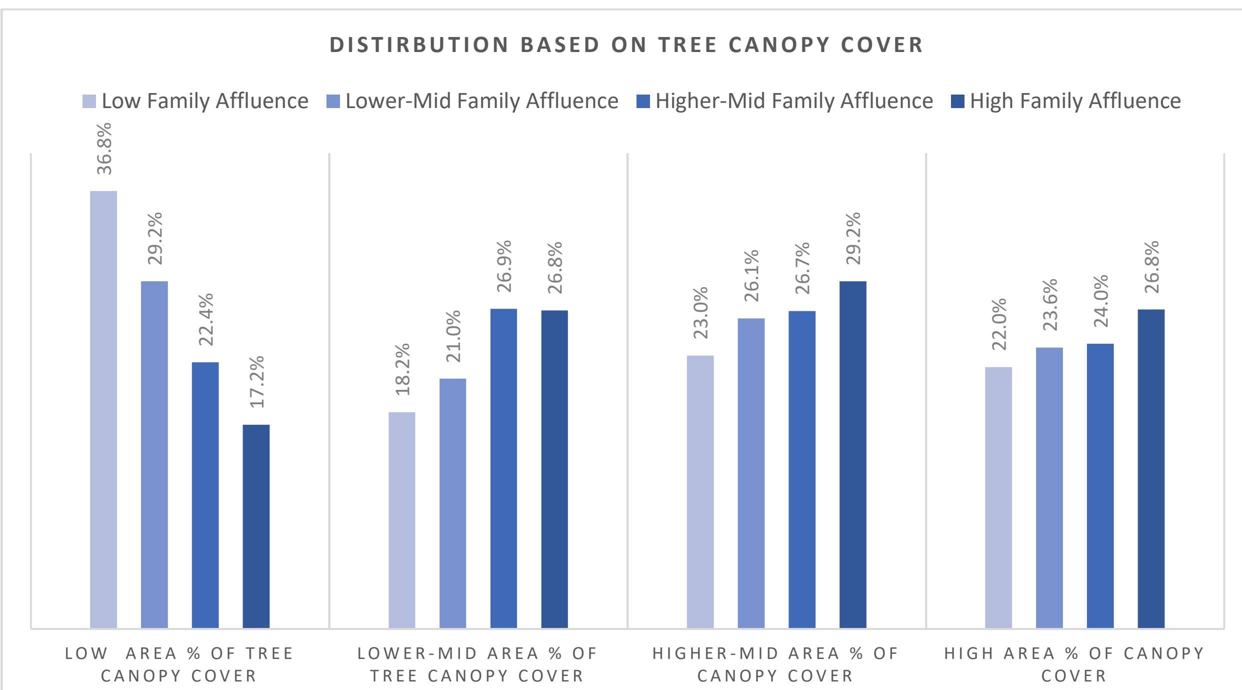


Figure 10: Distribution of respondents based on Tree Canopy Cover



5.1.2. Distribution of respondents who report severe Depressive symptoms by Available Greenspace vis-à-vis *Family Affluence*

With the addition of data pertaining to depressive and anxiety symptoms, it is now possible to visualize how mental health outcomes vary depending on greenspace availability vis-à-vis the level of family resources. In this part, respondents with severe depressive symptoms (those with a score of 3) were tallied based on the same equal 4 groups method for available neighborhood greenspace and family affluence. However, in this section, the respondents were further divided based on their gender. The goal is to see if equigenesis, or the narrowing of the health disparities between different socioeconomic groups, occurs in both gender groups. This is done by checking if the socioeconomic gradient is indeed narrower in the groups with more available greenspace. To measure the size of the gaps in each level of greenspace availability, the difference between adjacent socioeconomic groups were averaged (low vs. lower-mid, lower-mid vs. higher-mid, and higher-mid vs. high)

Figure 11 -13 shows that the socioeconomic gradient in severe depressive symptoms is more pronounced in the female group compared to the male group – with the latter showing a less straightforward pattern of gradient. This pattern is holds true for all three greenspace availability measures.

In terms of narrowing health gaps, each measure yielded different results. When the lowest *Average Neighborhood Greenness* group is excluded, the health gaps seem to be reduced with every progressive level for both gender groups. In the order of increasing *Average Neighborhood Greenness,* the average health gaps are: 2.99%, 0.73%, and 0.05% for males; and 7.46%, 6.84%, and 6.10% for females. However, this narrowing of health disparity is not present in the other two measures. It is important to note though that for the female respondents belonging to the most affluent group, the percentage reporting severe depression is consistently lower compared to other family affluence groups. additionally, when comparing respondents belonging to the high family affluence group across levels of greenspace availability, the high family affluence group living in areas with more available greenspace seem to have a lower percentage of respondents reporting severe symptoms. The visualizations indicate that the commonly seen socioeconomic gradient in health is more pronounced in the female group.

Figure 11: Distribution of respondents with severe depressive symptoms (Ave. Neighborhood Greenness)

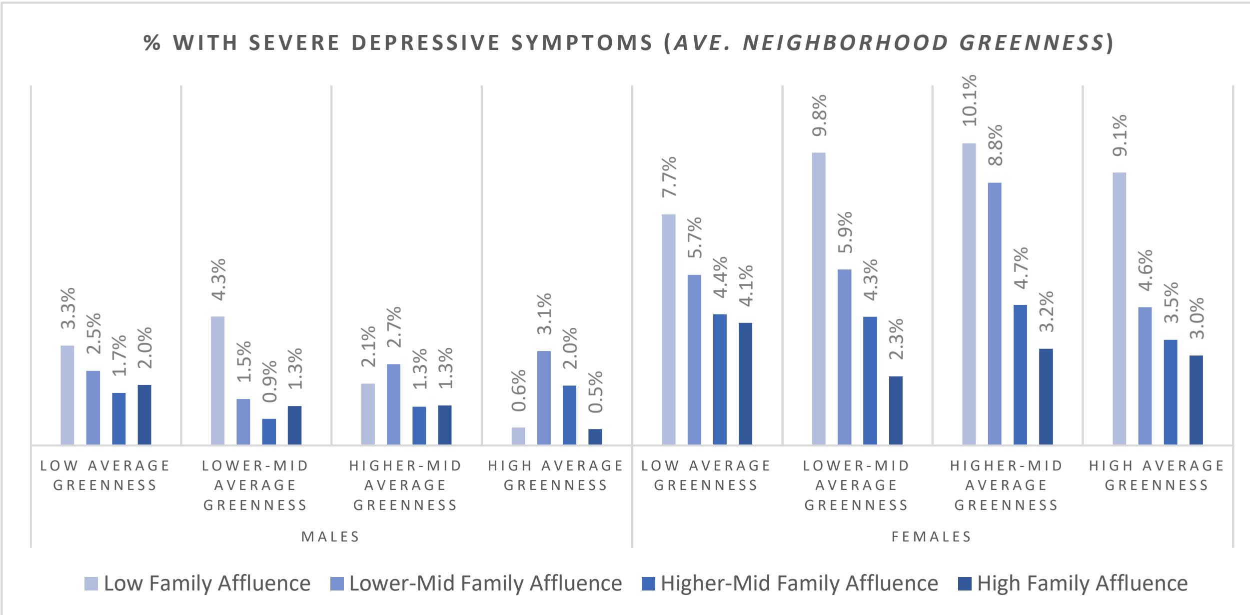


Figure 12: Distribution of respondents with severe depressive symptoms (Natural Cover)

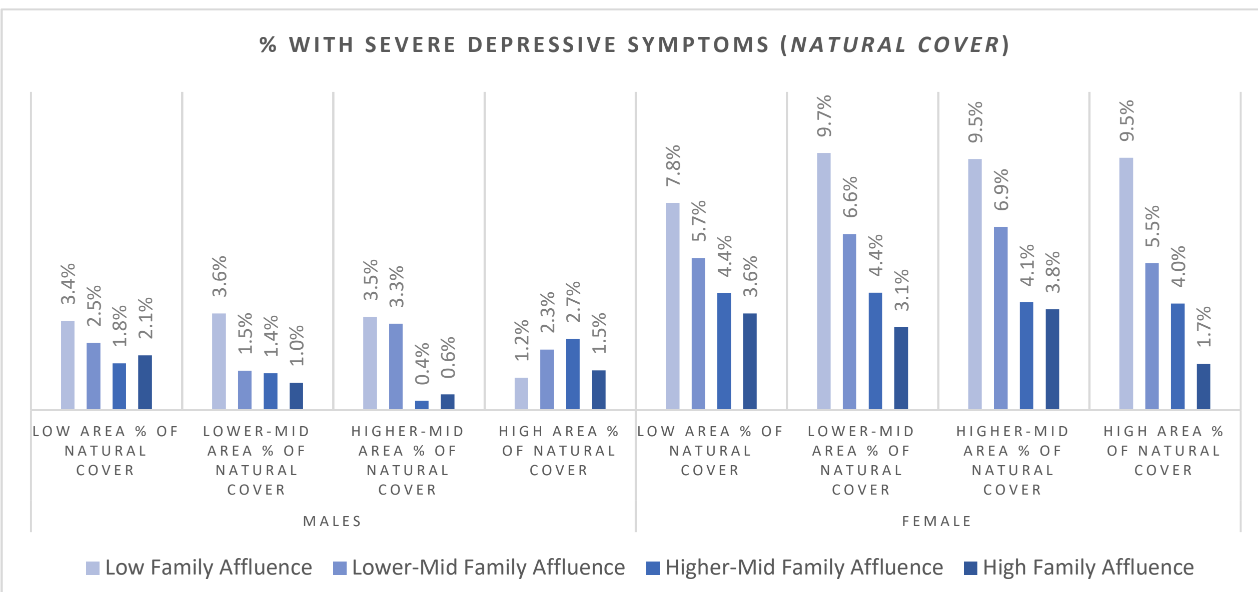
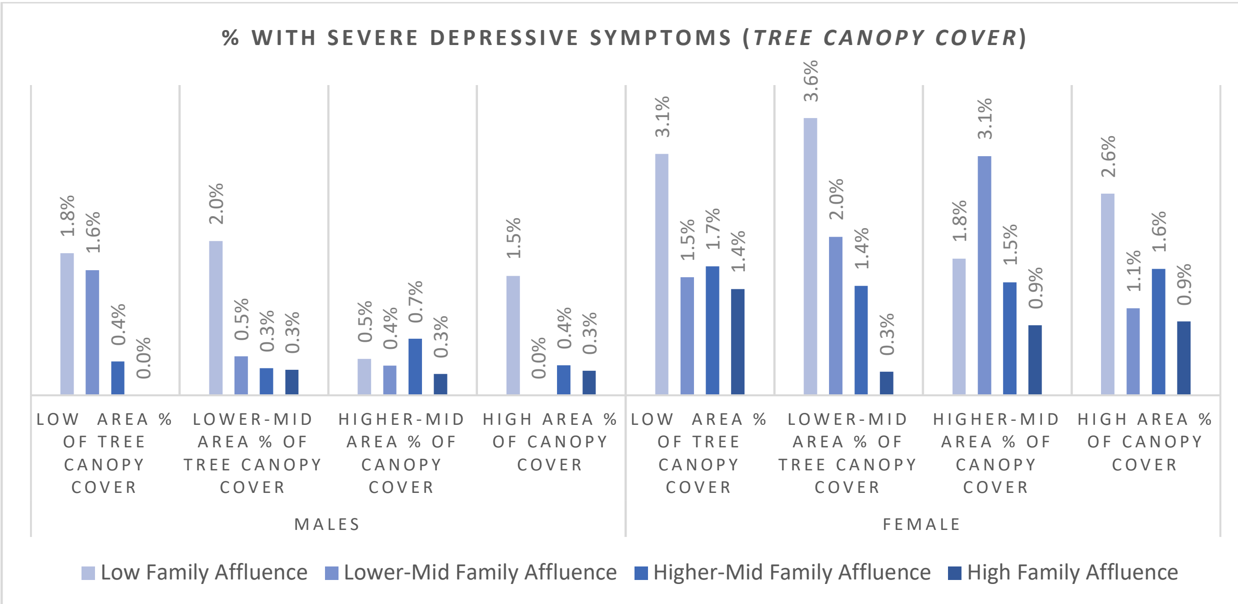


Figure 13: Distribution of respondents with severe depressive symptoms (Tree Canopy Cover)



5.1.3. Distribution of respondents who report severe Anxiety symptoms by Available Greenspace vis-à-vis *Family Affluence*

The same procedures were done to the second outcome variable of the study, *Anxiety.* Compared to the distribution of *Depression*, the distribution of severe anxiety symptoms does not show a very pronounced socioeconomic gradient. However, it is still clear that the groups with higher family affluence report less anxiety symptoms. When comparing the average gaps between different groups based on family affluence, equigenesis seem to be only present in the male respondents with the measures *Average Neighborhood Greenness* and *Natural Cover*. As previously done, when the lowest available greenspace group is excluded, the gaps in severe anxiety symptoms across different levels of *Family Affluence* seem to narrow. In the order of increasing greenspace availability, the average gap between socioeconomic groups in *Average Neighborhood Greenness* are: 2.45%, 0.78%, and 0.28%. For *Natural Cover,* the average gaps are: 2.52%, 1.90%, and 0.01%. This is narrowing of health gaps was not present in the female group using all three greenspace measures.

Figure 14: Distribution of respondents with severe anxiety symptoms (Ave. Neighborhood Greenness)

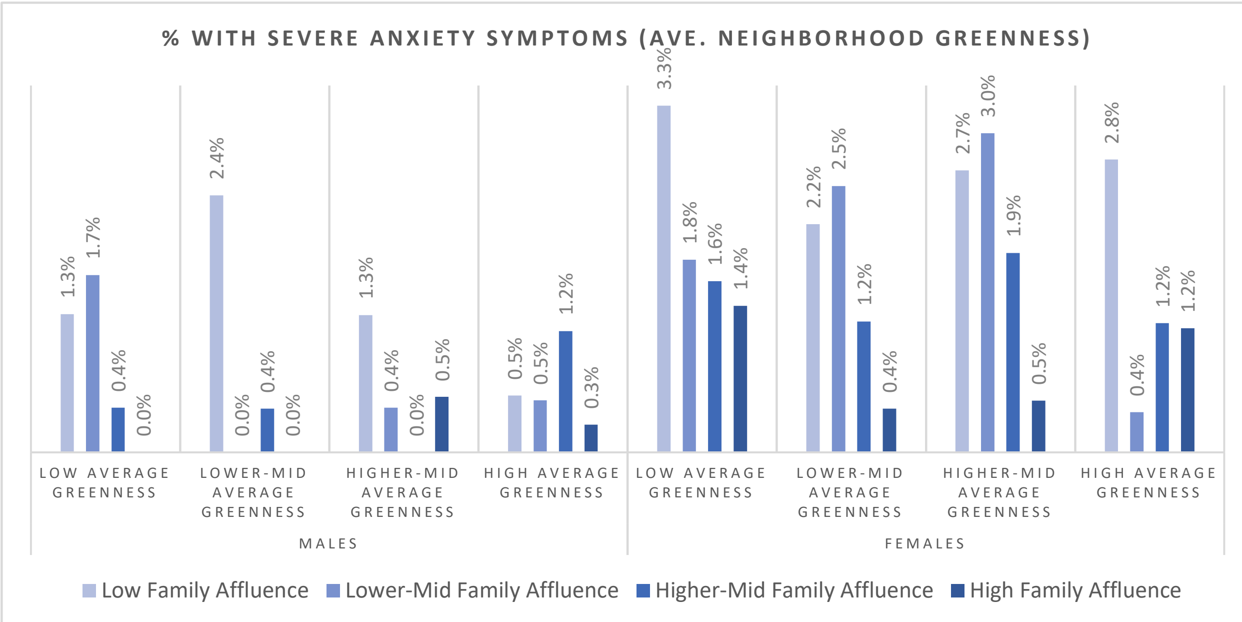


Figure 15: Distribution of respondents with severe anxiety symptoms (Natural Cover)

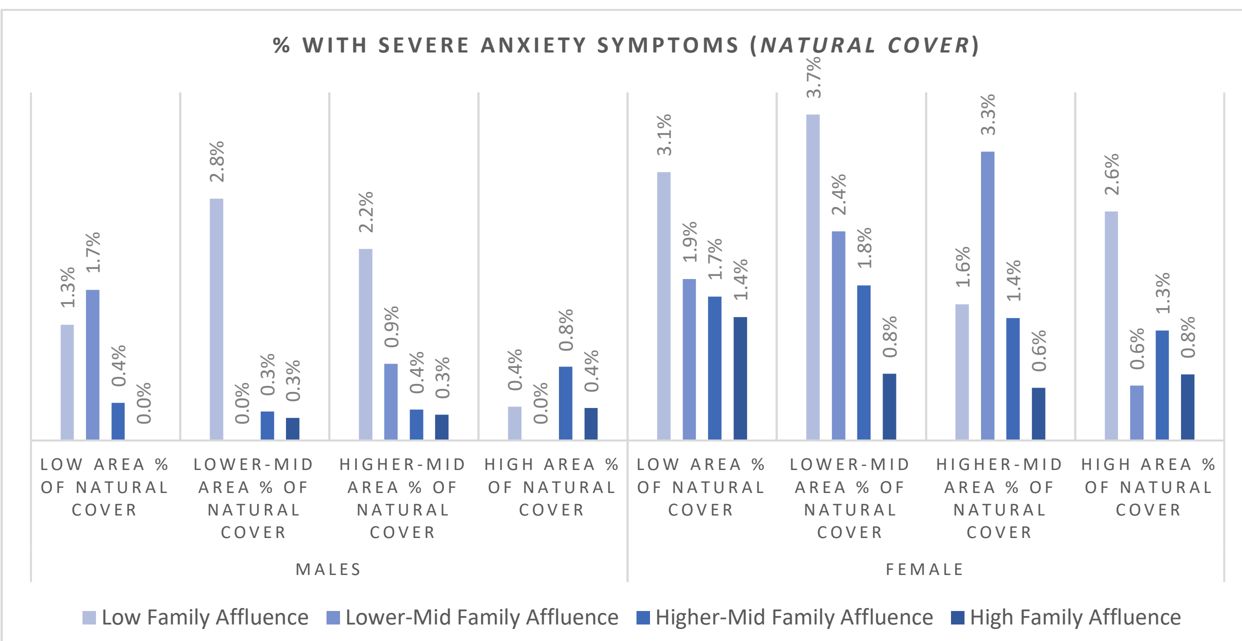
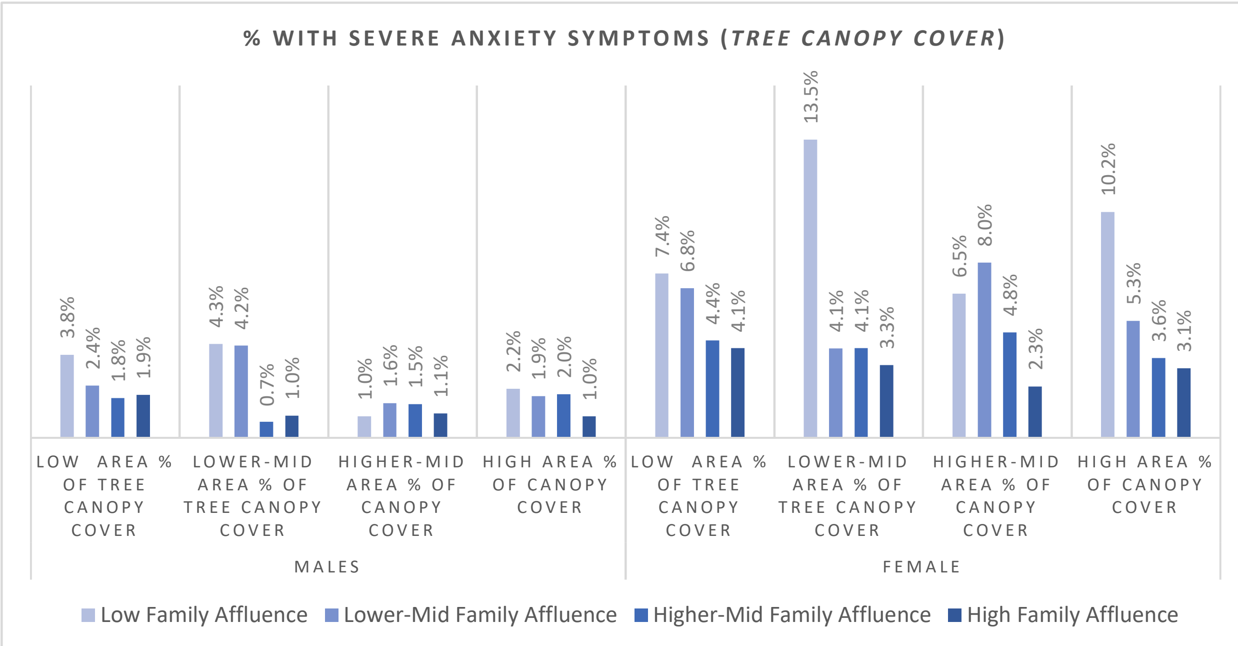


Figure 16: Distribution of respondents with severe anxiety symptoms (Natural Cover)



The distribution of the respondents across varying levels of family affluence and greenspace availability suggests that the relationship between the variables of the study can vary depending on gender, with the socioeconomic gradient being more pronounced in the female group. The succeeding part, which utilizes more robust statistical methods to analyze the different variables, is expected to shed some light into the complexity of the associations, including how much of a role neighborhood greenspace plays as a predictor of mental health

5.2. Bivariate Analysis: Pearson's Correlation

Three bivariate analyses are performed in this section. The first uses the entire dataset, which includes *Gender* as a variable, followed by two separate correlational analyses for each gender.

The results of Pearson's r correlation are presented in table 9 and it shows that almost all variables in the study are correlated, except for four variables when paired with *Gender*; there are no significant associations between *Gender* and *Family Affluence*, and *Gender* and all measures for neighborhood greenspace. This means that for the respondents of the study, being female neither means one is more likely to come from an affluent family or live in a neighborhood with a lot of greenspace.

Surprisingly, *Neighborhood Satisfaction* is correlated with only one *Neighborhood Greenspace* measure, *Average Neighborhood Greenness* (r = .022, $p < .05$), and shows a negative, but insignificant relationship with *Natural Cover* and *Tree Canopy Cover.*

Table 9: Bivariate correlation between the study variables

Correlation (Pearson's r)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Gender	1								
2. Family Affluence	0.003	1							
3. Neighborhood Satisfaction	-.071**	.131**	1						
4. School Satisfaction	-0.017	.162**	.411**	1					
5. Average Greenness	-0.014	.180**	.022*	.052**	1				
6. Natural Cover	-0.012	.072**	-0.02	0.018	.917**	1			
7. Tree Canopy Cover	-0.011	.086**	-0.015	0.01	.844**	.888**	1		
8. Depressed Mood score	.300**	-.061**	-.241**	-.209**	-.036**	-.040**	-.033**	1	
9. Anxiety score	.380**	-.074**	-.230**	-.176**	-.036**	-.041**	-.033**	.743**	1

**p<.01; *p<.05

[1]. 0 (Male), 1(Female)

[2]. 0 (low family affluence) to 3(high family affluence)

[3]. 0 (Low Neighborhood Satisfaction), 1 (high Neighborhood Satisfaction)

[4]. 0 (Low School Satisfaction), 1 (High School Satisfaction)

[5]. 0 (low average greenness) to 1 (high average greenness)

[6] 0 (low % of natural cover) to 100 (high % of natural cover)

[7]. 0 (low % of tree canopy cover) to 100 (high % of tree canopy cover)

[8]. 0 (no symptoms of depression) to 3 (severe symptoms of depression)

[9]. 0 (no symptoms of anxiety) to 3 (severe symptoms of anxiety)

Family Affluence is positively correlated with all three neighborhood greenspace measures: *Average Neighborhood Greenness* (r = .180, $p < .01$), *Natural Cover* (r = .072, $p < .01$), and *Tree Canopy Cover* (r = .086, $p < .01$). This indicates that respondents who come from more affluent families tend to live in neighborhoods with more available greenspace. This association is consistent with the results of the exploratory analysis conducted for this thesis (Appendix 1), where a positive association was found between average household income and greenspace availability in neighborhoods when pairing data from SSB and Urban EEA.

In terms of the outcome variables, *Family Affluence* is negatively correlated with *Depressed Mood* (r = -.061, $p < .01$) and Anxiety (r = -.074, $p < .01$), which indicates that respondent belonging in more affluent families are less likely to have depressive symptoms. Furthermore, *Gender* is positively correlated both with *Depressed Mood* (r = -.300, $p < .01$) and Anxiety (r = -.380, $p < .01$), suggesting that female respondents are more likely to report symptoms of depression and anxiety compared to their male cohorts. These results reiterate the earlier findings of the Young in Oslo Survey 2015 (Andersen and Bakken 2015).

Of interest to this study is the association between neighborhood greenspace and mental health outcomes. Bivariate analysis revealed that there is a significant negative correlation between *Depressed mood* all measures of neighborhood greenspace: *Average Neighborhood Greenness* (r = -.036, $p < .01$), *Natural Cover* (r = .040, $p < .01$), and *Tree Canopy Cover* (r = .033, $p < .01$).

Similarly, *Anxiety* is also negatively correlated with *Average Neighborhood Greenness* (r = -.036, $p < .01$), *Natural Cover* (r = -.041, $p < .01$), and *Tree Canopy Cove* (r = -.033, $p < .01$). This suggests that respondents living in neighborhoods with more greenspace tend to report less depressive and anxiety symptoms. These results are consistent with previous research where a linear relationship between greenspace and mental health outcomes were established, specifically, the more greenspace available (or accessible) correlates with better mental health outcomes.

Tables 10 and 11 presents the correlational analyses for males and females respectively. There are no major differences in the significance of the associations between *Family Affluence* and all greenspace measures, which means that more affluent male and female respondents tend to live in greener neighborhoods.

However, there are interesting differences between the genders in the associations between measures of neighborhood greenspace availability and *Neighborhood Satisfaction*.

For males, only *Average Neighborhood Greenness* is positively associated with *Neighborhood Satisfaction* (r = .045, $p < .01$), which means male respondents who have more available greenspace tend to report higher satisfaction with their neighborhoods. Most surprisingly for females, *Average Neighborhood Greenness* is not significantly associated with *Neighborhood Satisfaction*, while the two other measures are negatively correlated: *Natural Cover* (r = -.038, $p < .05$), *Tree Canopy Cover* (r = -.029, $p < .05$). This indicates that girls with more greenspace available in their neighborhoods tend to report lower neighborhood satisfaction. These results are at complete odds with research regarding greenspace and residential satisfaction, but it highlights that other omitted variables linked to greenspace availability might potentially have effects that were not accounted for.

Table 10: Bivariate correlation between the study variables for Males

Correlation (Pearson's r)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Family Affluence	1							
2. Neighborhood Satisfaction	.126**	1						
3. School Satisfaction	.161**	.427**	1					
4. Average Greenness	.191**	.045**	.061**	1				
5. Natural Cover	.079**	0	0.022	.917**	1			
6. Tree Canopy Cover	.093**	-0.003	0.005	.844**	.886**	1		
7. Depressed Mood score	-.092**	-.232**	-.198**	-.043**	-.038*	-.037*	1	
8. Anxiety score	-.116**	-.223**	-.179**	-.046**	-.041**	-.036*	.654**	1

**p<.01; *p<.05

In terms of the outcome variables, there is still a significant negative correlation between all measures of neighborhood greenspace and the outcome variables in the male group.

For the female group, however, only *Natural Cover* has a significant negative correlation with *Depressed mood.* As for *Anxiety,* there are still significant negative associations, but only between *Natural Cover* and *Tree Canopy Cover*. As a measure, *Average Neighborhood Greenness* is not significantly associated with any of the outcome variables in females.

The results of the correlational analysis suggest that there are differences in the association between greenspace availability and neighborhood satisfaction. Furthermore, the *Average Neighborhood Greenness* was not associated with any of the outcome variables of the study for the female group. This begs further investigation using multiple regression to understand how these variables interact in both genders in terms of predicting mental health outcomes.

Table 11: Bivariate correlation between the study variables for Females

Correlation (Pearson's r)	1	2	3	4	5	6	7	8
1. Family Affluence	1							
2. Neighborhood Satisfaction	.133**	1						
3. School Satisfaction	.163**	.397**	1					
4. Average Greenness	.161**	0.002	.045**	1				
5. Natural Cover	.057**	-.038*	0.012	.918**	1			
6. Tree Canopy Cover	.070**	-.029*	0.013	.844**	.891**	1		
7. Depressed Mood score	-.029*	-.229**	-.223**	-0.02	-.033*	-0.025	1	
8. Anxiety score	-.045**	-.222**	-.186**	-0.024	-.038**	-.029*	.753**	1

*p<.01; *p<.05

5.3. Multivariate Analysis

This section discusses the results from the hierarchical multiple regression conducted to test the hypotheses of the study. The dataset was split along the variable *Gender*, and separate analyses were performed to verify if availability of neighborhood greenspace affects each gender differently. The variables were distributed along five models, with models 4-5 having a different neighborhood greenspace measure each. Since each dataset exclusively has respondents belonging to one gender (either male of female), only *Family Affluence* is included in Model 1 as a background variable. Model 2 and 3 adds the environmental satisfaction variables, *Neighborhood Satisfaction* and *School Satisfaction* respectively.

The first three variables (*Family Affluence* and *Neighborhood* and *School Satisfaction*), plus the addition of one neighborhood greenspace variable, will form the full models for Models 4-6. In Model 4, *Average Neighborhood Greenness* is added. In Model 5, *Natural Cover*, and *Tree Canopy* was added in Model 6.

5.3.1. Depressed Mood

Table 9 shows the results of the regression analysis for *Males*. Model 1 explains 1.1% of the outcome *Depressed mood,* Model 2 explains 6%, and Model 3 explains 7%.

Model 1 shows a significant negative association between *Family Affluence* and *Depressed mood* (β = -.106, p < .001). In Model 2, the addition of the first environmental satisfaction variable, *Neighborhood Satisfaction,* lead to a statistically significant increase in R^2 of .049 (β = -.224, p <.001). In Model 3, the addition of *School Satisfaction* slightly increased the model's R^2 by .01 (β = -.113, p < .001).

Table 12: Hierarchical Regression for Depressed Mood in Males

Depressed Mood: Male		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		β (p-value)					
Background variable	*Family Affluence*	-.106***	-.077***	-.065***	-.061***	-.062***	-.062***
Environmental Satisfaction	*Neighborhood Satisfaction*		-.224***	-.177***	-.177***	-.177***	-.177***
	School Satisfaction			-.113***	-.112***	-.112***	-.113***
Neighborhood Greenspace	*Ave. Neighborhood Greenness*				-.017 (.278)		
	Natural Cover					-.030 (.055)	
	Tree Canopy Cover						-.028 (.068)
	R squared change (p-value)	.011***	.049***	.010***	.000 (.278)	.001 (.055)	.001 (.068)
	Adjusted R squared	0.011	0.06	0.07	0.07	0.071	0.071

***p<.001; **p<.01; *p<.05

Models 4-6 includes the addition of a single measure of neighborhood greenspace on top of the first three variables. The addition of *Average Neighborhood Greenness* did not lead to a statistically significant increase in R^2 in Model 4 (β = -.017, p = .278). There was also no statistically significant change in the R^2 in Model 5 (β = -.030, p = .055), and in Model 6 (β = -.028, p = .068).

The negative association between *Depressed Mood* and the independent variables *Family Affluence* is significant in all 6 models, as well as *Neighborhood Satisfaction* and *School Satisfaction* from models 2,3- 6 for *Males*. Conversely, all measures of neighborhood greenspace availability are not associated with *Depressed Mood*. These results indicate that male respondents whose family has a lot of resources and are satisfied with their neighborhood and school are less likely to be depressed. Additionally, when controlling for family resources and environmental satisfaction, neighborhood greenspace is not a significant predictor of *Depressed Mood.*

Table 13 shows the results of the regression analysis for *Females*. Model 1 explains .2% of the outcome *Depressed mood,* Model 2 explains 5.2%, and Model 3 explains 7.2%.

Model 1 shows a significant negative association between *Family Affluence* and *Depressed mood* (β = -.041, $p < .001$). In Model 2 *Neighborhood Satisfaction* was introduced, which increased the model's predictive power by 5% (β = -.226, $p < .001$). By Model 2 *Family Affluence* has become positive and insignificant (β = -.009, $p = .522$). *School Satisfaction* was introduced in Model 3 which lead to an increase in the predictive power of the model by 2.1% (β = -.158, $p < .001$). This suggests that previously significant effect of *Family Affluence* on *Depressed Mood* is possible mediated by environmental satisfaction – ergo, female respondents who are satisfied with their neighborhood and school are less likely to be depressed, regardless of their socioeconomic position.

Table 13: Hierarchical Regression for Depressed Mood in Females

Depressed Mood: Female		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		β (p-value)					
Background variable	*Family Affluence*	-.041**	-.009 (522)	.008 (577)	.011 (469)	.011 (.460)	.010 (476)
Environmental Satisfaction	*Neighborhood Satisfaction*		-.226***	-.166***	-.166***	-.168***	-.167***
	School Satisfaction			-.158***	-.158***	-.158***	-.158***
Neighborhood Greenspace	*Ave. Neighborhood Greenness*				-.015 (297)		
	Natural Cover					-.039**	
	Tree Canopy Cover						-.030*
	R squared change (p-value)	.022**	.050***	.021***	.000 (.297)	.002**	.001*
	Adjusted R squared	0.001	0.052	0.072	0.072	0.074	0.073

***p<.001; **p<.01; *p<.05

Models 4-6 includes the addition of a single measure of neighborhood greenspace on top of the first three models. The addition of *Average Neighborhood Greenness* did not lead to a statistically significant increase in R^2 in Model 4 (β = -.015, p = .297). However, the addition of *Natural Cover* lead to a statistically significant change in the R^2 in Model 5 (β = -.039, p < .01). In Model 6, the addition of *Tree Canopy Cover* also leads to a statistically significant change in the $R^{2\ in}$ (β = -.030, p < .05).

The negative association between *Family Affluence* and *Depressed mood* is only significant in Model 1. The introduction of *Neighborhood Satisfaction* lead to a change in the direction and significance level of *Family Affluence*'s association with *Depressed Mood* - effectively making it an insignificant predictor. More importantly, when controlling for *Family Affluence* and environmental satisfaction variables, *Natural Cover* and *Tree Canopy Cover* are still significant predictors of *Depressed Mood*. This would suggest that the availability of neighborhood greenspace is a significant predictor of *Depressed mood* among female respondents.

5.3.2. Anxiety

Table 11 shows the results of the regression analysis for *Males*. Model 1 explains 1.2% of the outcome *Anxiety,* Model 2 explains 5.6%, and Model 3 explains 6.2%.

Model 1 shows a significant negative association between *Family Affluence* and *Depressed mood* (β = -.108, p < .001). In Model 2, the addition of the first environmental satisfaction variable, *Neighborhood Satisfaction,* lead to a statistically significant increase in R^2 of .045 (β = -.213, p <.001). In Model 3, the addition of *School Satisfaction* slightly increased the model's R^2 by .007 (β = -.092, p < .001).

Models 4-6 includes the addition of a single measure of neighborhood greenspace on top of the first three models. The addition of *Average Neighborhood Greenness* did not lead to a statistically significant increase in R^2 in Model 4 (β = -.008, p = .596). There was also no statistically significant change in the R^2 in Model 5 (β = -.027, p = .078), and in Model 6 (β = -.024, p = .0127).

The negative association between *Anxiety* and the independent variable *Family Affluence* is significant in all 6 models, as well as *Neighborhood Satisfaction* and *School Satisfaction* from models 2,3- 6 for *Males*. Conversely, all measures of neighborhood greenspace availability are not associated with *Anxiety*. These indicate that male respondents whose family has a lot of resources and are satisfied with their neighborhood and school are less likely to have anxiety symptoms. Additionally, when controlling for family resources and environmental satisfaction, neighborhood greenspace is not a significant predictor of *Anxiety.*

Table 14: Hierarchical Regression for Anxiety in Males

Anxiety: Male		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		β (p-value)					
Background variable	*Family Affluence*	-.108***	-.081***	-.071***	-.069***	-.068***	-.068***
Environmental Satisfaction	*Neighborhood Satisfaction*		-.213***	-.175***	-.175***	-.175***	-.175***
	School Satisfaction			-.092***	-.092***	-.092***	-.092***
Neighborhood Greenspace	*Ave. Neighborhood Greenness*				-.008 (596)		
	Natural Cover					-.027 (.078)	
	Tree Canopy Cover						-.024 (.127)
	R squared change (p-value)	.012***	.045***	.007***	.000 (.596)	.001 (.078)	.001 (.127)
	Adjusted R squared	0.011	0.056	0.062	0.062	0.063	0.063

***p<.001; **p<.01; *p<.05

Table 15 shows the results of the regression analysis for *Females*. Model 1 explains .1% of the outcome *Anxiety,* Model 2 explains 4.9%, and Model 3 explains 6%.

Model 1 shows a significant negative association between *Family Affluence* and *Depressed mood* (β = -.052, p < .001). In Model 2 *Neighborhood Satisfaction* was introduced, which increased the model's predictive power by 4.7% (β = -.218, p < .001). By Model 2 *Family Affluence* has become insignificant (β = -.022, p = .134). *School Satisfaction* was introduced in Model 3 which lead to an increase in the predictive power of the model by 1.1% (β = -.114, p < .001).

As with *Depressed Mood,* the results for suggests that the previously significant effect of *Family Affluence* on *Anxiety* is moderated by environmental satisfaction. Female respondents who are satisfied with their neighborhood and school are less likely to have anxiety symptoms, regardless of their *Family Affluence*.

Models 4-6 includes the addition of a single measure of neighborhood greenspace on top of the first three models. The addition of *Average Neighborhood Greenness* did not lead to a statistically significant increase in R^2 in Model 4 ($\beta = -.016$, $p = .288$). However, the addition of *Natural Cover* lead to a statistically significant 0.2% change in the predictive power of Model 5 ($\beta = -.041$, $p < .01$). In Model 6, the addition of *Tree Canopy Cover* also leads to a statistically significant change in the R^2 ($\beta = -.031$, $p < .05$).

Table 15: Hierarchical Regression for Anxiety in Females

Anxiety: Female		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		β (p-value)					
Background variable	*Family Affluence*	-.052***	-.022 (134)	-.009 (528)	-.007 (660)	-.006 (.664)	-.007 (.643)
Environmental Satisfaction	*Neighborhood Satisfaction*		-.218***	-.175***	-.175***	-.177***	-.176***
	School Satisfaction			-.114***	-.114***	-.113***	-.113***
Neighborhood Greenspace	*Ave. Neighborhood Greenness*				-.016 (.288)		
	Natural Cover					-.041**	
	Tree Canopy Cover						-.031*
	R squared change (p-value)	.003***	.047***	.011***	.000 (.288)	.002**	.001*
	Adjusted R squared	0.001	0.049	0.06	0.06	0.061	0.06

***p<.001; **p<.01; *p<.05

The negative association between *Family Affluence* and *Anxiety* is only significant in Model 1. The introduction of *Neighborhood Satisfaction* lead to *Family Affluence*'s becoming an insignificant predictor of *Anxiety*. More importantly, when controlling for *Family Affluence* and environmental satisfaction, *Natural Cover* and *Tree Canopy Cover* are still significantly predictor of the outcome variable. This would suggest that availability of neighborhood greenspace is a predictor of *Anxiety* among female respondents.

6. Discussions

This chapter discusses the results in relation to the active hypotheses, as well as the issues regarding the post hoc analyses conducted to clarify the unexpected associations found. Study limitation and suggestions for future research will conclude the chapter.

6.1. Hypotheses and Findings

The results indicate that available neighborhood greenspace is only a significant predictor for *Depressed mood* and *Anxiety* in the female group. Furthermore, *Family Affluence* becomes an insignificant predictor of mental health when controlling for *Neighborhood Satisfaction* in the female group, while it remained significant in all the models in the male group. *Neighborhood Satisfaction* appears to be the strongest predictor of *Depressed Mood* and *Anxiety* in both genders, but the way in which the independent variables interacted showed marked differences. Table 16 provides a summary of the findings vis-à-vis the hypotheses of the thesis.

Table 16: Hypotheses and findings

Hypotheses	Findings
Hypothesis 1a: *Neighborhood greenspace is positively correlated with Family Affluence.*	supported
Hypothesis 2a: *Neighborhood greenspace availability is positively correlated with Neighborhood satisfaction.*	partially supported
Hypothesis 2b: *Neighborhood greenspace availability is negatively correlated with Depressed Mood and Anxiety.*	partially supported
Hypothesis 3: *There are differences in the standardized coefficients (β) of the predictor variables in the models comparing male and female respondents.*	supported

The statistical analyses performed offered support for the hypothesis 1a of the study. Specifically, neighborhood greenspace measures are associated with *Family Affluence.* This is true for both genders and indicates that respondents in Oslo who have a lot of family resources tend live in neighborhoods with more available greenspace. This is consistent with the exploratory analysis conducted for this thesis on Oslo's general population using average household income in lieu of *Family Affluence* (Appendix 1).

Hypothesis 2a is partially supported by the statistical analyses. When the dataset is analyzed as a whole, the only neighborhood greenspace availability measure associated with *Neighborhood*

Satisfaction is *Average Neighborhood Greenness* (r = .022, $p < .05$). When the file is split based on the grouping variable *Gender,* the association still holds, but only for males. Conversely in females, *Average Neighborhood Greenness* is not significantly correlated with *Neighborhood Satisfaction,* while the two other measures of greenspace availability are negatively correlated: *Natural Cover* (r = -.038, $p < .05$), *Tree Canopy Cover* (r = -.029, $p < .05$). These results are surprising as it indicates that the female respondents who live in neighborhoods with less available greenspace tend to report high satisfaction with their neighborhood. This adds another layer of complexity that was unexpected, as both greenspace measures and *Neighborhood Satisfaction* are also negatively correlated to *Depressed Mood* and *Anxiety*.

Hypothesis 2b is only partially supported. Gender differences play a prominent role in the relationship between neighborhood greenspace and mental health outcomes. When controlling for *Family Affluence* and *School Satisfaction*, higher neighborhood greenspace is only significantly associated with better mental health in female respondents.

Hypothesis 3 is supported by the regression analyses. There are substantial gender differences in terms of the interaction of *Family Affluence, Neighborhood* and *School Satisfaction,* and the amount of available neighborhood greenspace.

For males, *Family Affluence* is a significant predictor in all the models. Its validity as a predictor was not substantially changed by the introduction of environmental satisfaction and neighborhood greenspace measures. Furthermore, living in a green neighborhood had no impact in the mental health of the male respondents. The analyses also indicate that even when controlling for *School* and *Neighborhood Satisfaction*, how much family resources male adolescents have still plays an important role in their mental health outcomes.

This is in stark contrast with the results for the female group. As soon as *Neighborhood Satisfaction* was introduced in the model, the effects of *Family Affluence* immediately became insignificant in both *Depressed Mood* ($\beta = -.009$, $p = .522$) and *Anxiety* ($\beta = -.022$, $p = .134$). This suggests that *Neighborhood Satisfaction* could play a mediating role in effects of *Family Affluence* on mental health outcomes for females. The results also indicate that the level of family resource female respondents have plays very little role in predicting their mental health outcomes, so long as they are satisfied with their neighborhood and school environments.

This difference is very clear in comparing Model 1 in the two gender groups. The beta coefficients of for *Family Affluence* in males is almost double that in females. This is true for both *depressed mood* and *Anxiety*; males (β = -.106, $p < .001$) vs. females (β = -.041, $p < .001$), and males (β = -.108, $p < .001$) vs. females (β = -.052, $p < .001$) respectively. This suggest there's a stronger relationship between family resources and mental health for males than in females.

More importantly for this thesis, when controlling for *Family Affluence, Neighborhood Satisfaction* and *School Satisfaction*, the two measures of neighborhood greenspace availability, *Natural Cover* and *Tree Canopy Cover,* are shown to be significant predictors of mental health for the female group. In addition, upon the introduction of *Natural Cover* or *Tree Canopy Cover* in the model, there is an increase observed in the beta coefficients of *Neighborhood Satisfaction* and *Family Affluence*, though the latter remained insignificant. Multicollinearity was assessed for all the models using the tolerance and the variance inflation factor (VIF) to check if it caused these unexpected changes in the beta coefficients. The values ranged from .804 to 1.0 for tolerance, and 1 to 1.24 for VIF, which indicates that multicollinearity was not an issue.

Note that *Neighborhood Satisfaction* is negatively correlated with both *Natural Cover* and *Tree Canopy Cover* in the female group - while *Neighborhood Satisfaction* and *Natural Cover* variables are negatively correlated with the outcome variables *Depression* and *Anxiety*. This indicates that a possible *reciprocal suppression* is present as demonstrated by an increase in the magnitude of the regression coefficients in *Neighborhood Satisfaction* when either *Natural Cover* or *Tree Canopy Cover* is added in the model

A suppressor variable is defined as "a variable that increases the predictive validity of another variable (or set of variables) by its inclusion in a regression equation" (Conger 1974, quoted from Pandey and Elliot 2010). A suppressor works by accounting for (or suppressing) variation it shares with the other independent variables that are irrelevant to the outcome variable, thus improving the predictive power of the model (Pandey and Elliot 2010).

Given the unexpected results, the first series of post hoc analysis was conducted to assess if reciprocal suppression effects are present. The first analysis came in a form of a reversal in the step-wise inclusion of the predictor variables in the regression model (i.e. entering either *Natural*

Cover or *Tree Canopy Cover* first, followed by *Neighborhood Satisfaction*) to see if there is an increase in the beta coefficients of the two neighborhood greenspace measures when *Neighborhood Satisfaction* was added to the model. The results show that the inclusion of *Neighborhood Satisfaction* did increase the predictive validity of the two greenspace measures *Tree Canopy Cover* and *Natural Cover,* as assessed by the increase in their beta coefficients. However, it also revealed that *Tree Canopy Cover* was initially an insignificant predictor of *Depressed Mood*, and only became significant when controlling for *Neighborhood Satisfaction.* On the other hand, *Natural Cover* and *Tree Canopy Cover* were significant predictors of *Anxiety*, and their beta coefficients increased when *Neighborhood Satisfaction* was added. This indicates that suppression effect could be present.

To provide additional support for suppression effects between the predictor variables, post hoc analysis was conducted in the female group using a bootstrapping estimation approach with 5000 samples[23]. The SPSS macro used for this analysis was originally designed for test for mediation, but it can also be used to test for suppression as both are designed to assess third variable effects, and the statistics involved are basically identical (Mackinnon, Krull, and Lockwood 2000; Pandey and Elliot 2010). However, conceptual differences need to be emphasized. In a *mediational* hypothesis, it is predicted that the inclusion of a third variable in the model will decrease the strength of the association between the predictor and outcome variables because the mediator explains part, if not all, of the association. In contrast, when *suppression* is at play, the strength of the association is increased because some of the outcome-irrelevant variation shared by the predictor variables are suppressed, hence the name (Pandey and Elliot 2010).

Ludlow and Klein (2014) also discussed the nuance between variables *as* suppressors vs. *acting as* suppressors; with the former requiring an *a priori* hypothesis specifically looking for suppressor variables based on a theoretical framework, while the latter is only considered post hoc due to unexpected results. Here, the issue of causality needs to be addressed. Though the statistical tests used are the same, the underlying mechanisms in identifying suppression effects is purely mathematical and should not be regarded as implying causation (though the terms direct and mediated "effects" are used). Furthermore, as a post hoc analysis with no guiding theory,

[23] Using the SPSS macro PROCESS v.3 by Andrew F. Hayes http://www.processmacro.org/index.html

identifying specific variables *as* suppressors is not a requirement, and the results should only be regarded as offering support that a possible reciprocal suppression effect is present (ibid).

Two parameters within the mediation model output can provide support that suppression effects might be at play: the direct (τ') and mediated effects ($\alpha\beta$) of the independent variable have opposite signs, and the direct effect is larger than to total effect ($\alpha\beta + \tau$') (Tzelgov and Henik 1991; Mackinnon, Krull, and Lockwood 2000). Here, *Neighborhood Satisfaction* is entered in the macro as the mediator, but with a clear proviso that causality is not implied. Although direction-wise, it makes more sense to treat it as such because if one relates it to a realistic scenario, a change in greenspace availability may *cause* a corresponding change in satisfaction with one's neighborhood, but it is unlikely that a change in neighborhood satisfaction will cause a corresponding change in greenspace availability.

With *Depressed Mood* as the outcome variable, there is support that suppression is present. The direct and mediated effects are of opposite signs for both *Natural Cover* (τ' = -.0019, $\alpha\beta$ = .0005) and *Tree Canopy Cover* (τ' = -.0016, $\alpha\beta$ = .0004). In addition, their direct effects are larger than their total effects: *Natural Cover* (τ' = -.0019, $\alpha\beta + \tau$' = -.0014), *Tree Canopy Cover* (τ' = -.0016, $\alpha\beta + \tau$' = -.0012).

With *Anxiety* as the outcome variable, there is again support for suppression. The direct and mediated effects are of opposite signs for both *Natural Cover* (τ' = -.0020, $\alpha\beta$ = .0005) and *Tree Canopy Cover* (τ' = -.0017, $\alpha\beta$ = .0004). Additionally, their direct effects are larger than their total effects: *Natural Cover* (τ' = -.0020, $\alpha\beta + \tau$' = -.0015), *Tree Canopy Cover* (τ' = -.0017, $\alpha\beta + \tau$' = -.0013).

Another approach discussed by Pandey and Elliot (2010) in identifying the presence of a suppressor is when the semi-partial correlation of the variables is larger than their zero-order correlation when they are together in the model. Since reciprocal suppression is suspected, this condition would be true for *Neighborhood Satisfaction* and the two neighborhood greenspace variables. This can be easily seen in the coefficients table of the SPSS regression output.

With *Depressed Mood* as the outcome variable, there is additional support that suppression effects are present between the predictor variables. The semi-partial correlation is larger than the zero-order correlation for *Neighborhood Satisfaction* (r = -.229, semi-partial r = -.231) and *Natural Cover* (r = -.033, semi-partial r = -.041); and *Neighborhood Satisfaction* (r = -.229, semi-partial r = -.230) and *Tree Canopy Cover* (r = -.026, semi-partial r = -.033).

The same holds true with *Anxiety* as the outcome variable. The semi-partial correlation is again larger than the zero-order correlation for *Neighborhood Satisfaction* (r = -.222, semi-partial r = -.223) and *Natural Cover* (r = -.036, semi-partial r = -.045); and *Neighborhood Satisfaction* (r = -.222, semi-partial r = -.223) and *Tree Canopy Cover* (r = -.029, semi-partial r = -.036).

The analyses provide support that for the female group, reciprocal suppression is present between the two neighborhood greenspace measures and *Neighborhood Satisfaction*. This suggests that together in the model, they suppress outcome-irrelevant variation in each other as evidenced by a statistically significant increase in the model's predictive power (R^2), and an increase in their individual regression coefficients (β) upon their step-wise inclusion in the model.

Note that the regression coefficients of *Family Affluence* also increased when neighborhood greenspace measures were added in female group, though it remained insignificant. The same statistical tests were conducted to check for suppression effects, however the results did not offer support that it was present - apart from the increase in the beta coefficients. This is perhaps due to *Family Affluence* being potentially mediated by *Neighborhood Satisfaction.*

A second post hoc analysis was conducted, this time to explore if *Neighborhood Satisfaction* did mediate the relationship between *Family Affluence* and mental health outcomes in females - based on the latter becoming insignificant as soon as former was introduced in the model.

Here, the mediational model was also used, which again raised the issue of causality. Statistically speaking, the study design cannot imply a causative direction, however in a pragmatic sense, it is highly improbable that an increase in the respondents' *Neighborhood Satisfaction* can lead to an increase in their *Family Affluence*. In plain language, no matter how satisfied one becomes with one's neighborhood, it is unlikely that this will cause one's family to simultaneously have more resources – however, the reversal of this direction can be considered more plausible.

For *Depressed Mood* and *Anxiety,* the mediation hypothesis is supported. There is full mediation as shown by *Family Affluence* becoming an insignificant predictor when controlling for the effects of the mediator, and with a significant indirect effect of *Family Affluence* through *Neighborhood Satisfaction* for *Depressed mood* β = -.0354, SE = .0041, 95% CI (-.0436, -.0276), and *Anxiety* β = -.0346, SE = .0041, 95% CI (-.0430, -.0267).

The results of the statistical analyses indicate that *Neighborhood Satisfaction* is the strongest predictor of *Depressed Mood* and *Anxiety* among females, and it fully mediates the effects of their *Family Affluence* on their mental health outcomes, effectively making it an insignificant predictor. This was not observed in the male group.

More importantly, there appears to be substantial support that reciprocal suppression is present between *Neighborhood Satisfaction* and the neighborhood greenspace measures, *Natural Cover* and *Tree Canopy Cover* in the models predicting *Depression* and *Anxiety* among females. Though the significant effect sizes of *Natural Cover* and *Tree Canopy Cover* are minimal compared to that of *Neighborhood Satisfaction* when predicting *Depressed Mood* and *Anxiety*, their inclusion increases the overall predictive power of the model. This was not seen in the male group. The analyses provide further support for hypothesis 3, that there are substantial differences between the genders regarding the interplay of individual and environmental factors in predicting mental health outcomes.

6.1. Study Limitations

It's been theorized that when investigating the restorative qualities of immediate surroundings, specifically how much neighborhood greenspace is *available,* small circular buffers around one's point of residence should be used, i.e. 100-250 meters (Amoly et al. 2015; Markevych et al. 2017). Due to obvious ethical reasons, the administrative boundaries of Oslo were used in lieu of exact addresses. This basically means that the measure of *neighborhoods* used in this thesis can be considered crude compared to other greenspace studies. This inevitably leads to a question of validity regarding the neighborhood greenspace measures: are they accurately measuring the adolescents' immediate environment? This is quite important as there is an underlying assumption that restoration occurs when there are greenspaces near one's home - and in large neighborhoods in Oslo, it is entirely plausible that the adolescents are only exposed to a small part of their neighborhood (*delbydel*) because of their daily routes and routine. However, it should also be noted, that using mere administrative units have also found associations in other research (Mitchel and Popham, 2008; Beyer et al., 2014), and although crude, it can still provide a valid approximation of how much nature is available within Oslo's neighborhoods.

Another issue regarding the limitations of the study is the exclusion of other variables that might also lead to restoration. The variables for the study were limited to the variables included in the initial data request, and items such as the FASI II question asking respondents about owning their own room, can represent the availability of a resource that could provide restoration: a space to be alone. Furthermore, other important variables that could have an impact on mental health, such as quality of friendships, quality of parental relationships, were not controlled for in the study.

Quality of greenspace was also not controlled for, and this is due to the absence of information regarding the respondents' subjective evaluation of the greenspaces in their neighborhoods. Such items are not included in the Ungdata questionnaire, and to account for this, environmental satisfaction variables were included in the models. However, when asked about their satisfaction with their school and neighborhood, the respondents' evaluation could have been based on social characteristics of the environment, as opposed to physical ones. This is particularly important as there are research suggesting that quality of greenspace might have more of an impact than quantity when it comes to mental health (Francis et al. 2012).

Lastly, Ludlow and Klein (2014) in discussing analytic strategies in approaching and interpreting suppression emphasizes caution when claiming suppression is present, as it may imply a causal mechanism – which is problematic when there is no theory guiding the analyses, and accuracy regarding the measures of what constitutes a "neighborhood" is in question.

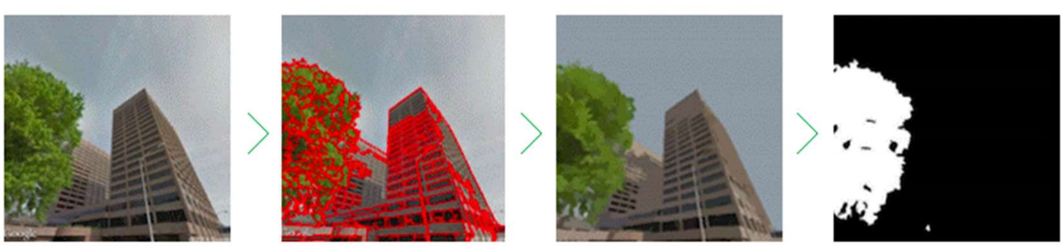
However, the exploratory analysis (Appendix 1) offers some background information that might elucidate the suppression effects seen between the variables included in the analysis. There is a pattern regarding immigrant background that was not accounted for in the present thesis. Based on the exploratory analysis, the concentration of certain immigrant groups in neighborhoods is associated with how rich and green the neighborhoods are. Connecting this to the present thesis, immigrant background is an omitted variable in the analyses, and it is associated with greenspace measures at the general population level - which in turn is also correlated with the other variables in the dataset used in the analysis. Perhaps it can be interpreted that immigrant background plays a role in predicting mental health outcomes, but since it was not included in the present thesis, components that it shares with the greenspace availability measures, *Family Affluence* (as a proxy for average household income), and *Neighborhood* Satisfaction is somewhat accounted for when they are all included in the model. This notion, of course, should be approached with healthy skepticism, and replication of studies claiming suppression effects are necessary to examine if it is indeed occurring (Mackinnon, Krull, and Lockwood 2000). However, the results of both the exploratory analysis and the present thesis should provide enough impetus for further research exploring the complexity of the relationships between the variables used, and those that were omitted.

6.2. Suggestions for further research

The limitations discussed in the previous part offer directions for further research. These will be discussed in the context of data used in this thesis and guidance from greenspace literature.

First, it is important to highlight that all the data one needs in exploring the effects of greenspace in various health and social outcomes for Oslo's youth are already available using the Young in Oslo surveys and the Urban EEA project's data layers. The three greenspace indicators used in this thesis are only a small fraction of the data available for researchers interested in the subject. For instance, the Green View Index[24] for Oslo is already available. This measure is perhaps the most valuable in exploring the restorative qualities of Oslo's neighborhoods because it gives a closer approximation of *viewable* greenery the adolescents are exposed to by using Google Street view images (Markevych et al. 2017; Grauwin et al. 2011; X. Li et al. 2015) (Figure 17).

Figure 17: GVI analysis of a Google Street View image, from senseable.mit.edu/treepedia

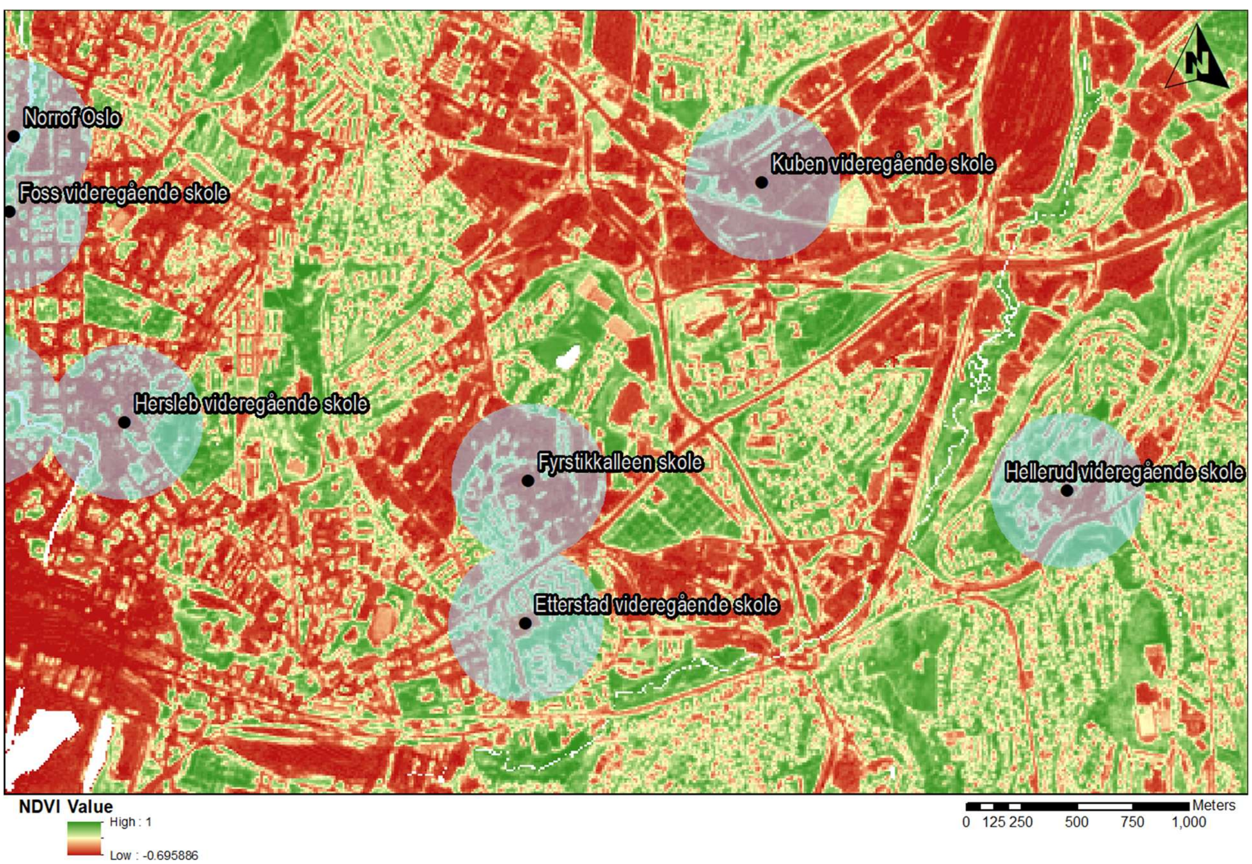


[24] Green View Index data by Zofie Zimburova http://urban.nina.no/layers/geonode%3Agvi_oslo_byggesonen

As mentioned in the limitations of the study, measuring greenspace availability ideally involves drawing a circular buffer around a respondent's home. Previous research have often measured associations based on different buffer sizes and comparing how the results vary (Villanueva et al. 2015; Amoly et al. 2015; Wu et al. 2014). Using this more accurate method was not possible for this thesis due to obvious ethical and privacy reasons. An alternative could be drawing a buffer around the school because such information is already available (Figure 18).

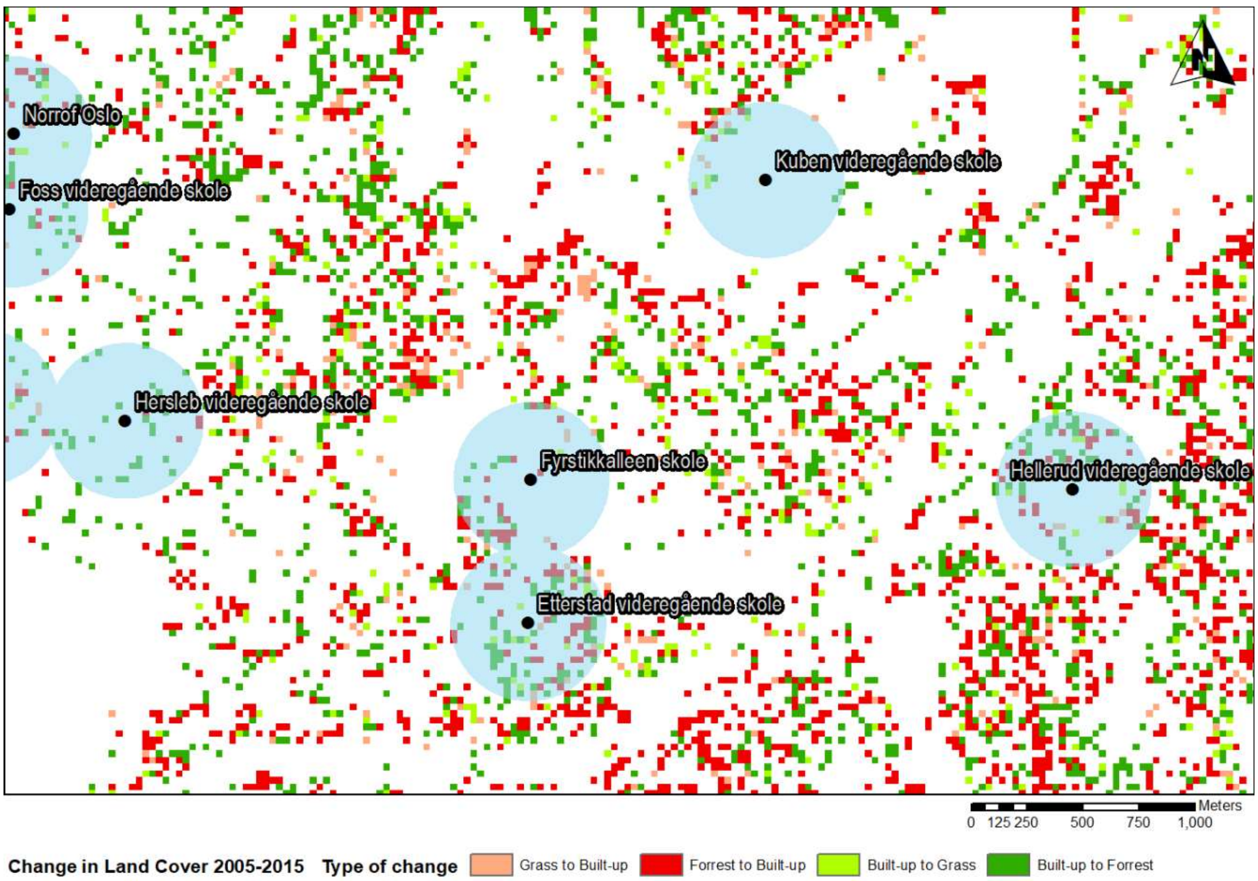
This offers an exciting opportunity to explore greenspace's capacity to affect various health and social outcomes because it can effectively measure the availability of greenspaces in their *immediate* school surrounding - and the problem regarding the measurement of neighborhood environments in this thesis can be fully addressed. This has been done on several greenspace studies which has found an association between surrounding school greenery and positive emotional well-being (Huynh et al. 2013), and school-wide performance in English and Math (Wu et al. 2014).

Figure 18: NDVI data view. The points represent schools with a 300m circular buffer.



Another data that might provide valuable insights when combined with the Young in Oslo survey is the land cover change from the years 2005-2015[25]. This layer offers a look of the changes along 5 different cartographical categories of land cover that have occurred in the past 10 years. Longitudinal data from Young in Oslo is available, and with the data regarding land cover change, researchers can gain insight if the reduction of greenspace availability around schools have led to corresponding changes in some outcomes (e.g. school satisfaction, reports of aggression) (Figure 19).

Figure 19. Land cover change (2005-2015). The points represent schools with a 300m circular buffer.



In terms of the psychological restoration pathway, the school's buffer allows for a kind of replication of Kuo and Sullivan's study (2001) mentioned in Chapter 3 regarding aggressive behavior. As guided by the research of the Kaplans (1989, 1991), aggression was seen as a product of mental fatigue characterized by the inability to control impulses that are socially

[25] Land cover change for Oslo from 2005-2015 by Zofie Zimburova.
http://urban.nina.no/layers/geonode%3Alc2005_plu_lc2015

unacceptable. Using this as a guiding principle, one can measure if the availability (or lack thereof) of greenspaces around schools are associated with aggressive behavior among students. The notion that the teenagers are influenced by the physical make-up of am environment they spend a substantial amount of their time in can have profound implications on urban equality. This kind of research would be valuable for local governments who are interested in understanding how adolescent well-being can be promoted through changes in their school's physical environment. This, of course, would entail additional privacy protocols such as anonymizing the schools.

Second, both the Young in Oslo survey and Urban EEA project offers opportunities in controlling for the other pathways between greenspace and health presented in Chapter 1 while focusing on the stress reduction and psychological restoration pathway. Composite measures corresponding to *physical activity* and *social cohesion* can be created using items from Ungdata. Measures for harmful factors in the environment, such as *air pollution*, is already available in the urban EEA layer archive[26] [27]. With these data, the interaction of pathways that lead to specific outcomes can be controlled for depending on the guiding theory, thus providing a more nuanced analysis of greenspace's effects on health.

Finally, it is this researcher's hope that items pertaining to greenspaces be included in future Ungdata questionnaires as a supplementary module. This can be included in the set of questions asking about their satisfaction with various aspects of their lives (*fornøydhet*) or included as a separate set of questions that assess their satisfaction and perception of accessibility in their local greenspaces. This data can be useful to gauge efficacy of greenspace interventions, especially its effects on perceived safety – which is already an existing item in Ungdata (*trygghet i nærmiljøet*). Time spent in greenspaces, including larger areas such as forests in the boundaries of cities, could also be incorporated to monitor level of usage and perception of quality. This might allow for the municipalities in Norway to incorporate the viewpoints of the youth in their cities by allowing them to evaluate their neighborhood greenspaces, considering it is a part of Norway's commitment to several international agreements.

[26] PM10 pollution data map by Megan Nowell http://urban.nina.no/layers/geonode%3Apm10_8hoyestedogn_grid
[27] NO2 pollution data map by Megan Nowell http://urban.nina.no/layers/geonode%3Ano2_grid

7. Conclusion

This thesis examined the interplay of the independent variables *Family Affluence, Neighborhood* and *School Satisfaction,* and neighborhood greenspace availability (*Average Neighborhood Greenness, Natural Cover* and *Tree Canopy Cover*) in predicting *Depressed mood* and *Anxiety*. The results indicated that there are substantial gender differences in the way these variables interact as predictors of mental health. *Neighborhood Satisfaction* is found to be the strongest predictor for both gender groups, but the way it interacts with the other variables reveal stark differences.

In the female group, the statistical analyses reveal that *Neighborhood Satisfaction* completely mediates the effects of *Family Affluence*, effectively making it an insignificant predictor of mental health. Post hoc analysis also offered support that reciprocal suppression may be present between *Neighborhood Satisfaction* and the greenspace measures *Natural Cover* and *Tree Canopy Cover* - which means that their predictive validity is increased when they are together in the model. Among the three neighborhood greenspace measures, *Natural Cover* and *Tree Canopy Cover* are found to be significant predictors of *Depressed mood* and *Anxiety.* In the order of decreasing power, *Neighborhood Satisfaction, School Satisfaction,* and *Neighborhood Greenspace* are significant predictors of mental health outcomes in the female group.

For the male group, none of the greenspace measures are significant predictors of *Depressed mood* and *Anxiety.* The statistical analyses conducted did not offer support for reciprocal suppression effects between *Neighborhood Satisfaction* and the greenspace measures, and *Neighborhood Satisfaction* did not mediate the relationship between *Family Affluence* and mental health outcomes. In the order of decreasing power, *Neighborhood Satisfaction, School Satisfaction,* and *Family Affluence* are significant predictors of mental health outcomes in the male group.

The final hypothesis regarding gender differences in the effects of neighborhood greenspace, in relation to their socioeconomic level and environmental satisfaction, is provisionally supported by the statistical analyses performed in this thesis.

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Appendix 1. Exploratory Data Analysis

This exploratory analysis was conducted to see if there is an uneven distribution of residents in Oslo based on greenspace availability and socioeconomic neighborhood characteristics. This analysis will essentially provide impetus for exploring how the variation in greenspace availability might potentially lead to varying mental health outcomes in the adolescents of the city. Oslo's "green" reputation also presents additional motivation for exploring if socio-spatial inequalities exist in one of the world's greenest cities.

1. Green Oslo

Based on the two conceptualizations of greenspace exposure proposed by the WHO (Thompson et al. 2016, 21), Oslo ranks highly in both *availability* and *accessibility* measures.

In terms of greenspace availability, an exploration of major European cities[28] using the Normalized Difference Vegetation Index (NDVI) puts Oslo in second place for greenest seaside capital in Europe following Monaco. NDVI provides a score ranging from -1 to +1, with higher values indicating healthy greenery, and negative values denoting water or vapor. The comparison divided the capital cities based on their latitudes and longitudes to reflect the type of climate and vegetation, as well as dividing them based on population numbers. The top three greenest European metropoles with populations of over 2 million are Kiev (NDVI .389), Berlin (NDVI .246), and Rome (NDVI .17); while the top three greenest seaside capitals are Monaco (NDVI .439), Oslo (NDVI .436), and Stockholm (NDVI .377).

Beyond these two measures, Oslo also ranks high in terms of satisfaction with the green areas of the city, which can be a proxy indicator for greenspace quality. Based on the Eurostat report[29] satisfaction in Oslo's green areas is high at >89%. Although most European cities score highly in

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[28]European cities comparison using NDVIhttps://philippgaertner.github.io/2017/10/european-capital-greenness-evaluation/

[29] Eurostat report on Urban Europe http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_-_statistics_on_cities,_towns_and_suburbs_-_green_cities

satisfaction (73/79 cities), Oslo stands out for being one of the 14 cities where an overwhelming majority of inhabitants report high satisfaction with their green areas (9/10 respondents).

Oslo is also faring well based on a new measure created by the Senseable project of the Massachusetts Institute of Technology (MIT) for measuring viewable greenery: The Green View Index (GVI) [30]. This innovative system maps viewable tree canopy in major cities around the world using Google Streetview images[31], and data from Oslo was recently made available. Oslo is again one of the greenest capital cities to be mapped so far – the 3rd greenest following Tampa and Singapore. GVI is one of the most innovative new ways to measure greenness pertinent to restorative environments research as it provides a closer approximation of actual viewable greenery in an area.

However, greenspace accessibility has been decreasing in Oslo. Greenspace in this context is represented by *recreational areas* and *areas for recreational walking*[32]. As of 2016[33], around 47% of Oslo's population has access to recreational areas, down from 52% in 2013. For people under the age of 20, around 51% have access, down from 56% in 2013. On the other hand, 27% percent of Oslo's residents have access to areas for recreational walking, down from 37% in 2013. For people under the age of 20, 32% has access, which is also down from 44% in 2013.

These numbers may suggest that the city is falling behind in terms of Norway's commitment to the Parma Declaration[34] and the Sustainable Development Goals (goal 11.7)[35]. However, it is still one of the greenest cities in the world whose inhabitants report high satisfaction with the greenspaces in the city. Exploring whether the within-city variation in greenspace availability could offer insights not only for greenspace research in general, but also on how features in the physical environment interacts with both socioeconomic and personal factors in affecting health outcomes.

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[30] Comparison of capital cities around the world using the Green View Index (GVI) http://senseable.mit.edu/treepedia/cities/oslo

[31] Google Streetview https://www.google.com/streetview/

[32] Statistics Norway (SSB) publication on safe access to recreational areas https://www.ssb.no/en/natur-og-miljo/artikler-og-publikasjoner/more-people-have-access-to-recreational-areas

[33] SSB saved query http://www.ssb.no/en/statbank/sq/10006602/

[34] Parma Declaration document http://www.euro.who.int/en/publications/policy-documents/parma-declaration-on-environment-and-health

[35] Sustainable Development goal 11 https://sustainabledevelopment.un.org/sdg11

2. Purpose of the analyses

The purpose of the exploratory analysis is to see how the population is distributed across Oslo's neighborhoods based on country/region of origin. An over and under-representation of minority groups in some neighborhoods would suggest unevenness is present in Oslo. The second goal is to see if the distribution is associated with certain neighborhood characteristics, specifically: *average household income* and *average property price per sq. m.*, and greenspace availability as measured by *Average Neighborhood Greenness (NDVI), Natural Cover,* and *Tree Canopy Cover.*

Combing SSB data[36] [37] with the Urban EEA[38] maps, data analysis was conducted at the neighborhood (*delbydel*) levels of Oslo to see if there is an association between the neighborhood factors, including greenspace availability, and percentage of population with immigrant background. Total count of the population is provided at the neighborhood level which can be further grouped based on country/region of origin[39].

To get a more nuanced look at the distribution of the population, several grouping schemes based on immigrant background were used. The main grouping is based on a Wester-Other division, the second is based on geographic regions, and the lowest basic division comprised of specific countries (or group of countries) within the geographic regions.

The Wester-Other division of immigrant background has four (4) groups based on percentage of the population who are originally from Norway, Western countries (excl. Norway), Non-Western countries (excl. Eastern Europe), and Non-Western countries (incl. Eastern Europe).

The group *Western countries (excl. Norway)* is further divided in to four (4) regions: EU and EEA, the Nordic region, Western Europe (others), and the last region comprising of the USA, Canada, Australia, and New Zealand. These countries/regions have no additional subdivisions under them.

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[36] Statistics bank for the Oslo municipality statistikkbanken.oslo.kommune.no/webview/index.jsp
[37] Average Income per neighborhood in Oslo (delbydel) - https://goo.gl/fa8iis
[38] Overview of the Urban EEA project https://goo.gl/mGRP4R
[39] Population based on Immigrant background Oslo https://goo.gl/sbYK8v

Non-Western countries (excl. Eastern Europe) is composed of five (5) regions: Africa, Turkey and the Middle East, South Asia, East Asia and Oceania, and South and Central America. Each region is further subdivided into countries except for region of South and Central America, which has no specified subdivision underneath it.

The region of *Eastern Europe* has four (4) basic divisions: Poland, EU countries in Eastern Europe including Cyprus, countries in the former Yugoslavia, and a group of unspecified Eastern European countries.

The region of *Africa* has four (4) basic divisions: countries form Sud-Saharan Africa, Eritrea and Ethiopia, Somalia, and a group of unspecified African countries.

The region of *Turkey and the Middle East* has four (4) basic divisions: Turkey, Afghanistan, Iraq, and Iran.

The region *South Asia* has three (3) basic divisions: Pakistan, Sri Lanka, and India.

The region *Southeast Asia and Oceania* has two (2) basic divisions: Vietnam, and other Asian countries including Oceania.

The percentage of population who are originally from Norway and Western countries will serve as a reference group and will be included in the bivariate correlation analysis with the other regions and basic divisions.

3. Greenspace, Household Wealth, and Property Prices

The statistical analysis shows that there is a positive correlation between *Average Neighborhood Greenness* and the *Average Household Income* in the neighborhoods of Oslo ($r = .305$, $p<.01$). This indicates that neighborhoods with richer households tend to be greener. This relationship is visualized in Figure 1. However, all greenspace availability measures are negatively correlated with *Average Property Price per sq. m.*: *Average Neighborhood Greenness* ($r = -.467$, $p<.01$), *Natural Cover* ($r = -.557$, $p<.01$), and *Tree Canopy Cover* ($r = -.498$, $p<.01$). This is probably due to the more expensive property prices of the central business districts of Oslo which also have more built-up areas compared to the greener suburban areas. Results of the first round of bivariate analysis is presented in Table 1.

4. Norwegian population and the Western-Others division

Table 1 also show positive correlations between the percentage of the population who are originally from Norway and *Average Household Income* (r = .692, p<.01), *Average Property Price per sq. m.* (r = .551, p<.01) and *Average Neighborhood Greenness* (r = .228, p<.05). These indicates that on an average, neighborhoods with a higher percentage of residents who are from Norway are more likely to have more affluent households, more likely to have expensive properties, and more likely to have more available greenspace. The relationship between percentage of population who are form Norway and property prices is visualized in Figure 2.

Table 1. Bivariate analysis for neighborhood factors & % of residents from different regions

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9
1. Average Household Income (2011-2015)	1								
2. Average Property Price per sq. m. (2015)	.384**	1							
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1						
4. Natural Cover (%)	0.171	-.557**	.946**	1					
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1				
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1			
7. % of population from Western countries (excl. Norway)	.424**	.754**	-.389**	-.417**	-.319**	.357**	1		
8. % of population from Non-Western countries (excl. Eastern Europe)	-.664**	-.700**	-0.029	0.123	0.014	-.959**	-.516**	1	
9. % of population from Non-Western countries	-.690**	-.676**	-0.087	0.069	-0.029	-.978**	-.506**	.992**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The percentage of population with a background from Western countries is also positively correlated with *Average Household Income* (r = .424, p<.01) and *Average Property Price per sq. m.* (r = .754, p<.01). However, there is a negative correlation observed with all greenspace availability measures: *Average Neighborhood Greenness* (r = -.389, p<.01), *Natural Cover* (r = -.417, p<.01), and *Tree Canopy Cover* (r = -.319, p<.01). These results indicate that although

Figure 1. Comparison between Average Household Income and Average Neighborhood Greenness (r = .305, p<.01)

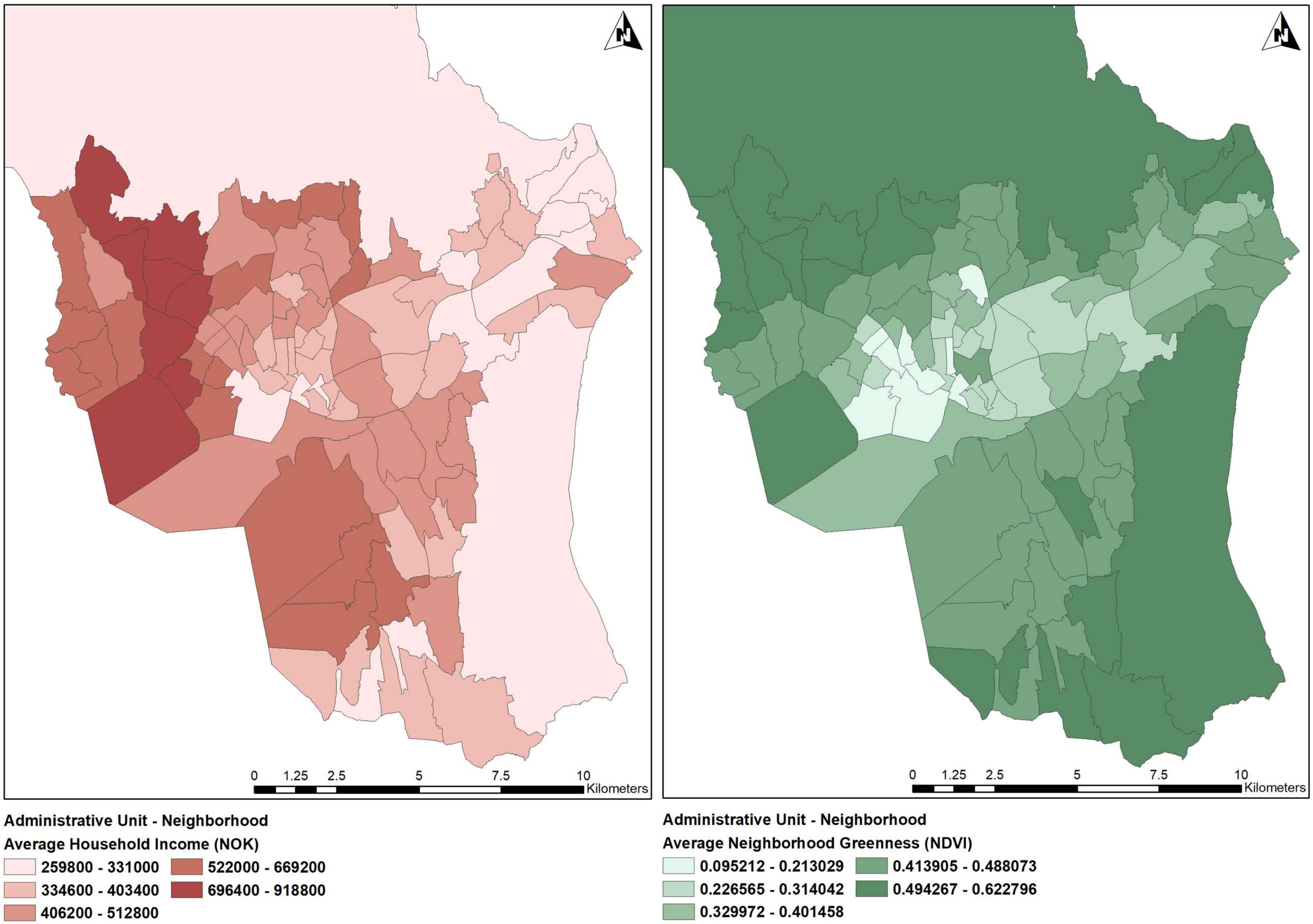


Figure 2. Comparison between Average Property Price per sq. m. and percentage of population originally from Norway (r = .551, p<.01).

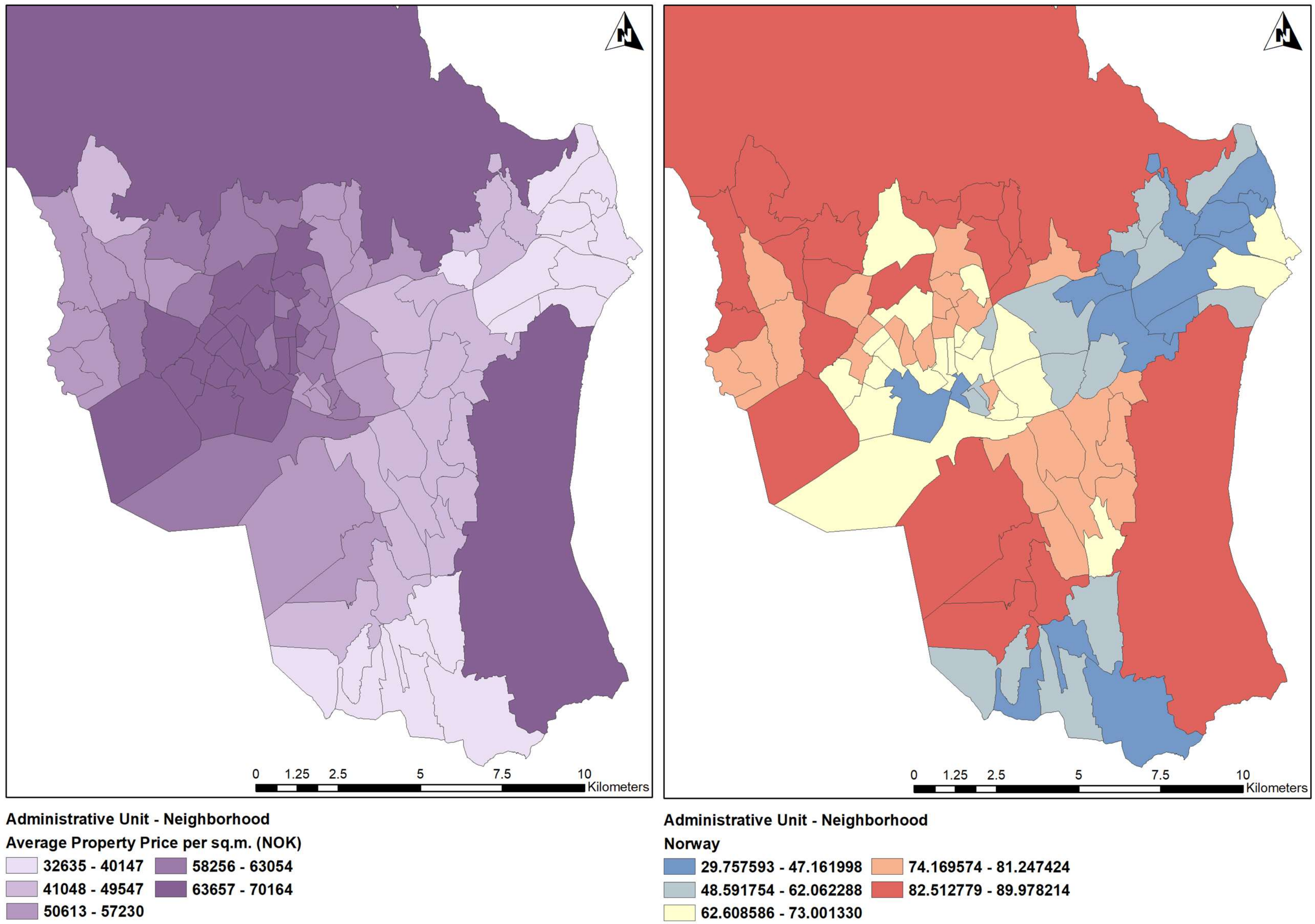
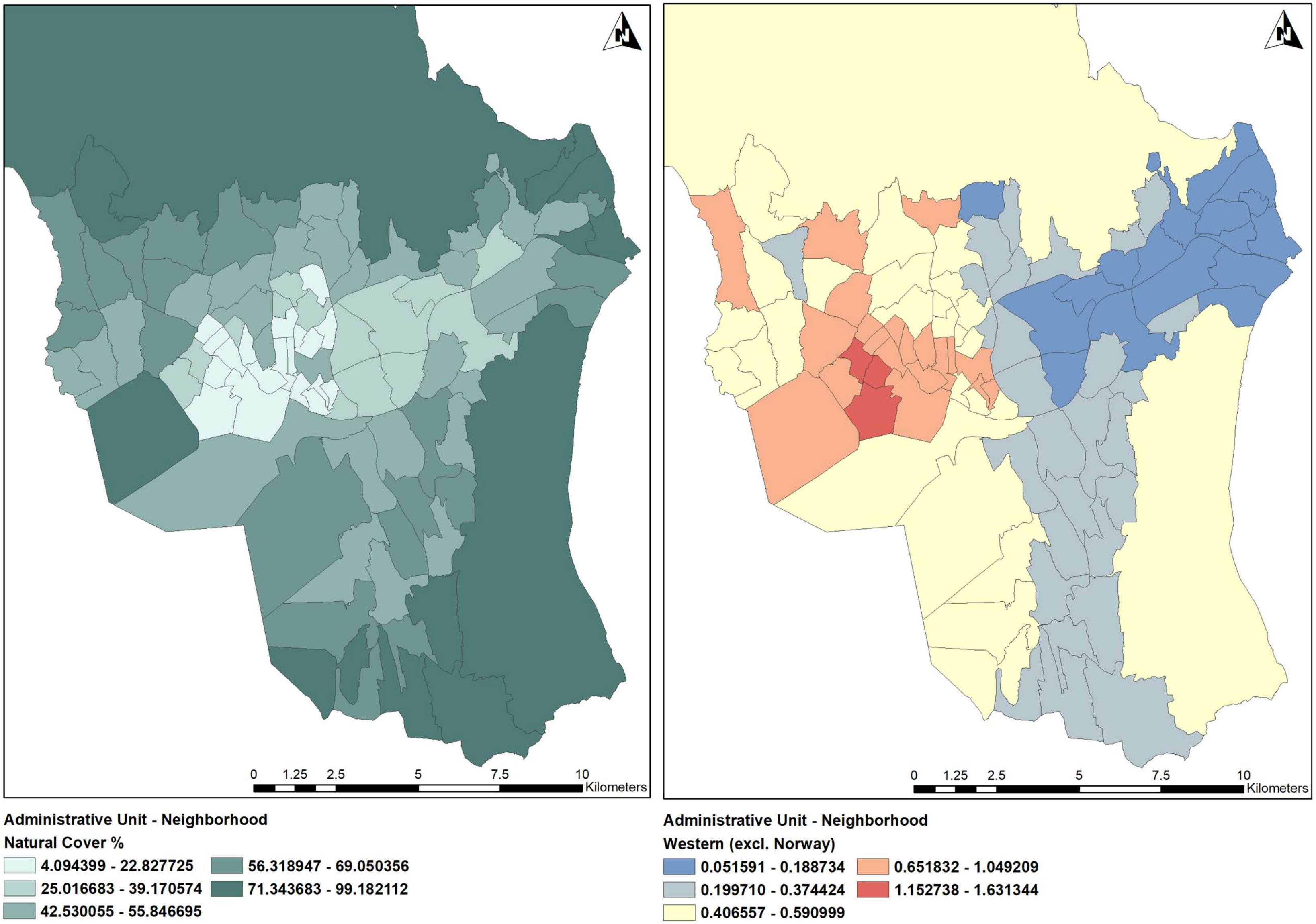


Figure 3. Comparison between Natural Cover and percentage of population originally from Western countries ($r = -.417$, $p<.01$).



western immigrants tend to live in neighborhoods with higher household income and property prices, they are more likely to have less greenspaces. This relationship is visualized in Figure 3.

In contrast, there is a negative correlation found between percentage of population with a background from *Non-Western countries (excl. Eastern Europe)* and *Average Household Income* (r = -.664, p<.01), *Average Property Price per sq. m.* (r = -.700, p<.01). The same negative correlation is found between percentage of population with a background from *Non-Western countries (incl. Eastern Europe)* and *Average Household Income* (r = -.664, p<.01), *Average Property Price per sq. m.* (r = .700, p<.01). Both groups did not show a significant association with any of the greenspace availability measures. This indicates that the non-western immigrants (with and without the eastern European group) tend to live in neighborhoods with lower household income and lower property prices.

5. Norwegian and Western population compared with other regions

Certain details are expected to be lost due to the simplicity of the Wester-Other division. The second round of bivariate analysis divides the non-western groups into different regions. The results are presented in Table 2.

The percentage of population with a background from *Eastern Europe* is negatively correlated with *Average Household Income* (r = -.604, p<.01), *Average Property Price per sq. m.* (r = -.326, p<.01), and all measure of neighborhood greenspace availability: *Average Neighborhood Greenness* (r = -.366, p<.01), *Natural Cover* (r = -.257, p<.05), and *Tree Canopy Cover* (r = -.259, p<.05). This indicates that neighborhoods with a high percentage of residents with an eastern European background tend to have lower household income, lower property prices, and less available greenspace. The relationship between percentage of population from eastern Europe and greenspace availability is visualized in Figure 4.

The percentage of population with an *African* background is negatively correlated with *Average Household Income* (r = -.703, p<.01) and *Average Property Price per sq. m.* (r = -.475, p<.01). However, there is no significant associations found with regards to available neighborhood greenspace. This indicates that neighborhoods where a high percentage of its population are of African descent tend to have lower household income and lower property prices.

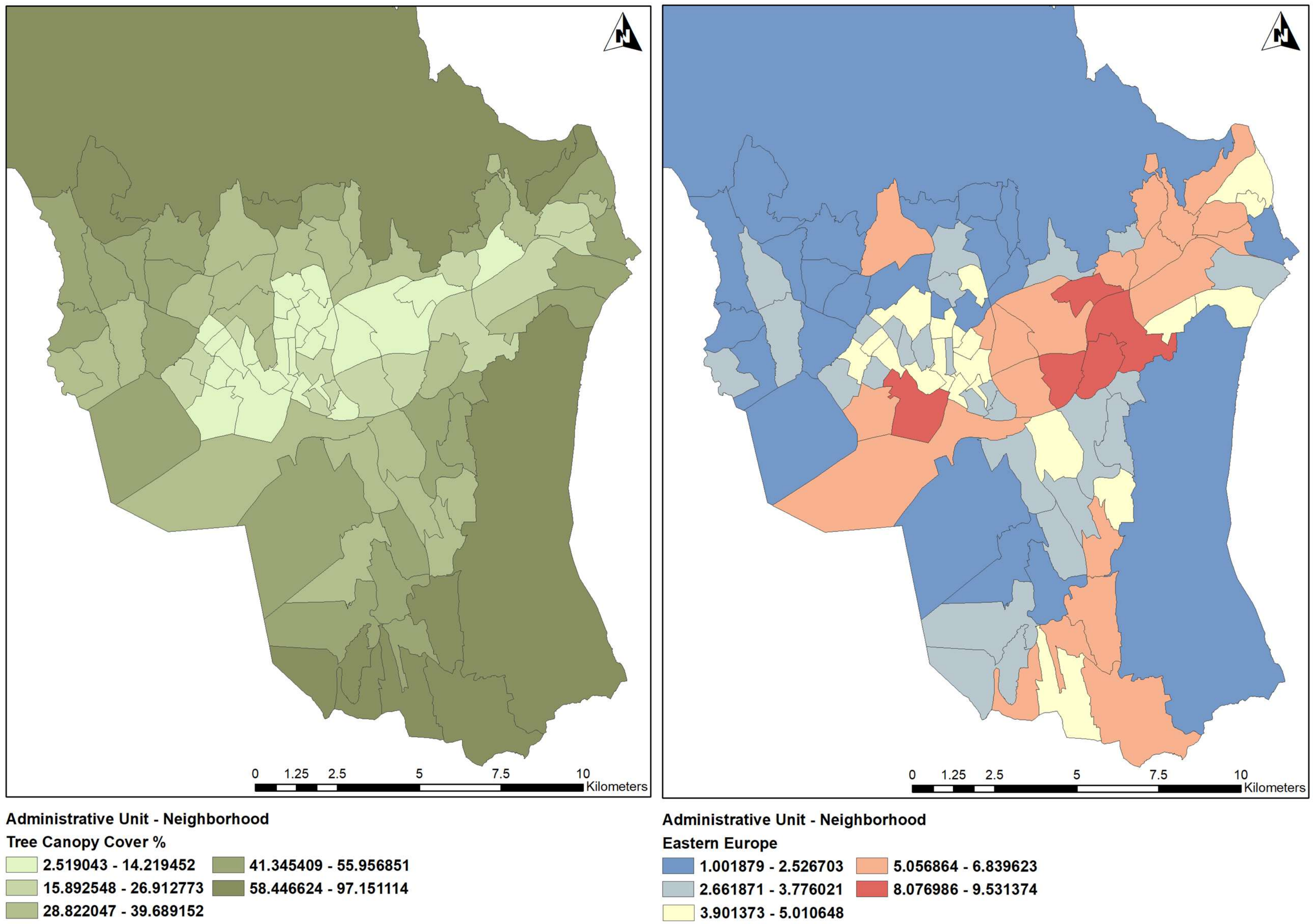
Table 2. Bivariate analysis for neighborhood factors & % of residents from different regions.

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Average Household Income (2011-2015)	1												
2. Average Property Price per sq. m. (2015)	.384**	1											
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1										
4. Natural Cover (%)	0.171	-.557**	.946**	1									
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1								
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1							
7. % of population from Western countries excl. Norway	.424**	.754**	-.389**	-.417**	-.319**	.357**	1						
8. % of population from Eastern Europe	-.604**	-.326**	-.366**	-.257*	-.259*	-.746**	-.294**	1					
9. % of population from Africa	-.703**	-.475**	-0.191	-0.078	-0.147	-.849**	-.378**	.558**	1				
10. % of population from Turkey and the Middle East	-.631**	-.670**	-0.039	0.087	-0.017	-.915**	-.526**	.676**	.795**	1			
11. % of population from South Asia	-.545**	-.765**	0.135	.283**	0.166	-.858**	-.535**	.480**	.667**	.859**	1		
12. % of population from Southeast Asia and Oceania	-.548**	-.466**	-.227*	-0.048	-0.140	-.896**	-.331**	.701**	.732**	.799**	.692**	1	
13. % of population from South and Central America	-.406**	0.137	-.576**	-.475**	-.430**	-.466**	.223*	.510**	.467**	.302**	0.064	.495**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 4. Comparison between percentage of population originally from Eastern Europe and Tree Canopy Cover (r = -.259, p<.05).



The percentage of population with a background from *Turkey and the Middle East* is also negatively correlated with *Average Household Income* (r = -.631, p<.01) and *Average Property Price per sq. m.* (r = -.670, p<.01). However, there was no significant associations found with regards to available neighborhood greenspace. This indicates that neighborhoods where a high percentage of its residents with a Turkish and the Middle Eastern background tend to have lower household income and lower property prices.

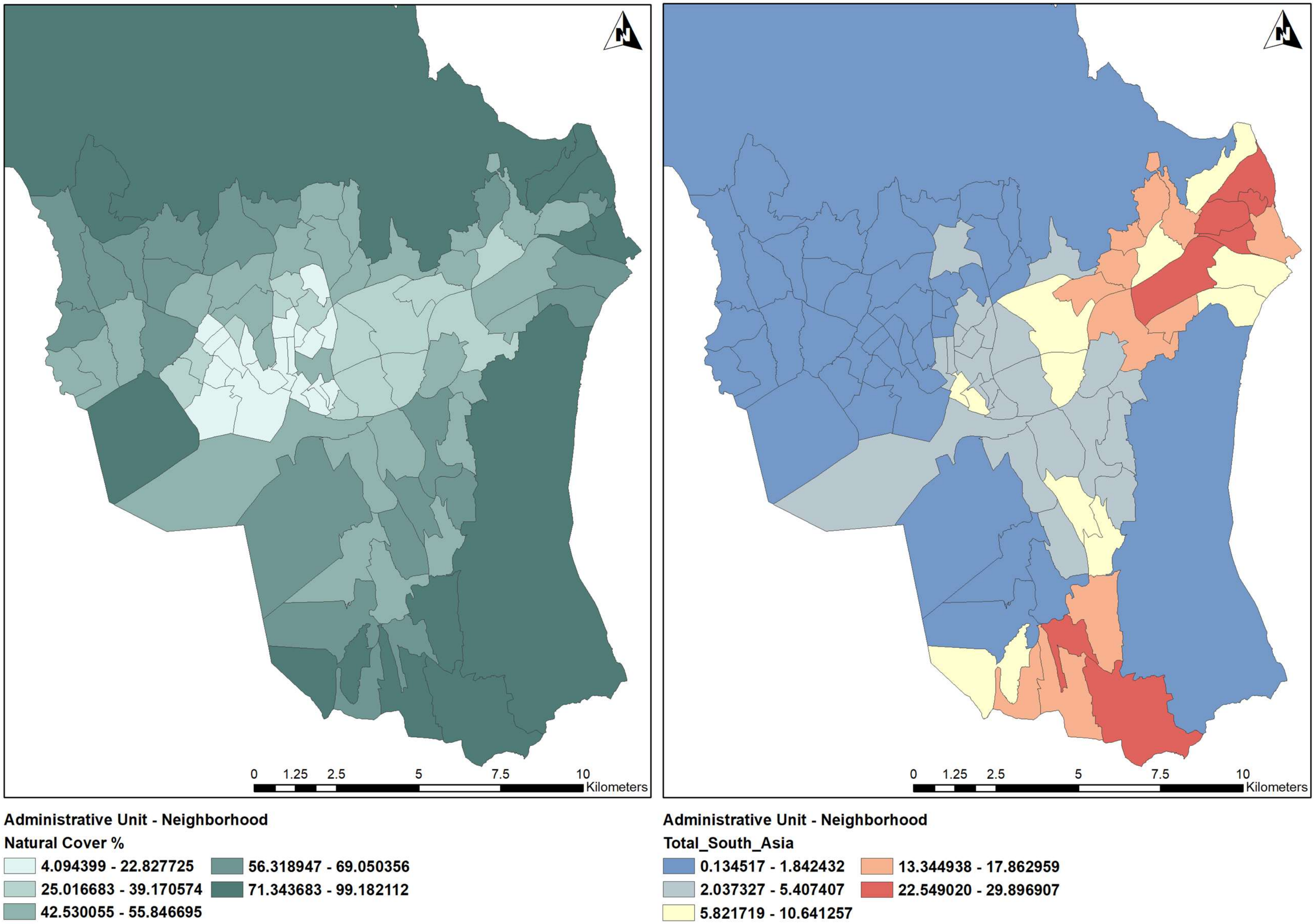
The same holds true for the percentage of the neighborhood's population with a background from South Asia: *Average Household Income* (r = -.545, p<.01) and *Average Property Price per sq. m.* (r = -.765, p<.01). However, percentage of population is positively correlated with *Natural Cover* (r = .283, p<.01). This indicates that although neighborhoods with a higher percentage of residents who are from south Asia tend to have lower household income and lower property prices, they also tend to have more available greenspace. This relationship is visualized in Figure 5.

As with the previous non-western regions, the percentage of population with a background from *Southeast Asia and Oceania* is negatively correlated with *Average Household Income* (r = -.548, p<.01)*, Average Property Price per sq. m.* (r = -.466, p<.01), and *Average Neighborhood Greenness* (r = -.227, p<.05). This indicates that neighborhoods where a high percentage of its residents are from southeast Asia and Oceania tend to have lower household income, lower property prices, and less available greenspace.

The percentage of population who are from *South and Central America* shows an interesting pattern as well. The percentage of population is negatively correlated with Average *Household Income* (r = -.406, p<.01), and all greenspace availability measures: *Average Neighborhood Greenness* (r = -.576, p<.01), *Natural Cover* (r = -.475, p<.05)*,* and *Tree Canopy Cover* (r = -.430, p<.05). However, there is no significant relation found in terms of *Average Property Price per sq. m.* This indicates that although neighborhoods that have a high percentage of residents who are from south and central America tend to have lower household income and less greenspace available, they don't necessarily have lower or higher property prices.

There appears to be an interesting pattern when the non-western group is divided into different regions. Neighborhoods where a high percentage of residents have non-western backgrounds tend to consistently have lower household income no matter the region of origin. The same

Figure 5. Comparison between percentage of population originally from South Asia and Natural Cover (*r* = .283, *p*<.01).



holds true for property prices, except for residents with a south and central American background. However, in terms of greenspace availability, the picture is not as consistent. There is no association found between greenspace availability measures and having a high percentage of residents with a background from Africa, Turkey and the Middle East. However, there is a significant negative correlation with all greenspace measures and percentage of residents who are from Eastern Europe and South and Central America. Only *Average Neighborhood Greenness* is negatively correlated with the percentage of population with background from Southeast Asia and Oceania. Furthermore, there is a positive correlation between *Natural Cover* and percentage of residents with a South Asian background.

This round of analysis reveals that there is nuance in the way Oslo's residents are distributed based on their regional background. As with residents who are originally from other western countries, residents from different non-western regions tend to live in neighborhoods with less available greenspace, except for those who have a South Asian background.

Finally, the analysis also shows that there is an interesting socio-spatial gradient in the neighborhoods of Oslo. Neighborhoods with a high ethnic Norwegian population tend to have higher household income, higher property prices, and more greenspace availability. Neighborhoods with a high percentage of residents with western backgrounds also tend to have higher household income and higher property prices, but they have less greenspace availability. And finally, neighborhoods with a high percentage of residents from most non-western regions have lower household income, lower property prices, and less available greenspace.

6. Analysis for individual regions

The final round of analysis involves taking a closer look at individual regions to see which country/group of countries, skew the results for the regions as a whole. The results of the analyses are presented in tables 3-8.

6.1. Western Regions

Table 3 shows the results of the bivariate analysis conducted for neighborhood factors and the different regions. As with neighborhoods with a high population percentage of ethnic

Norwegians, most neighborhoods with a lot of residents who are from other western countries (except for EU and EEA and Nordic countries) also tend to have higher household incomes and higher property prices. However, as mentioned in the previous section, most of these neighborhoods also tend to have low greenspace availability.

Table 3. Bivariate analysis of neighborhood factors & % of residents from western regions

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9	10
1. Average Household Income (2011-2015)	1									
2. Average Property Price per sq. m. (2015)	.384**	1								
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1							
4. Natural Cover (%)	0.171	-.557**	.946**	1						
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1					
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1				
7. % of population from EU and EEA countries	0.036	.598**	-.629**	-.563**	-.462**	-0.010	1			
8. % of population from Nordic Countries	0.057	.686**	-.645**	-.589**	-.473**	0.120	.925**	1		
9. % of population from Western Europe (others)	.321**	.735**	-.496**	-.482**	-.410**	0.200	.860**	.839**	1	
10. % of population from USA, Canada, Australia, and New Zealand	.424**	.754**	-.389**	-.417**	-.319**	.357**	.649**	.678**	.863**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

6.2. Eastern European Countries

The bivariate analysis for Eastern European countries also reveal an interesting pattern. The percentage of residents with a background from Poland and countries from the former Yugoslavia are not correlated with any of the greenspace availability measures. However, there is a significant negative correlation with *Average Household Income* (r = -.289, p <.01) and *Average Property Price per sq. m.* (r = -.257, p<.05). Conversely, the percentage of population with backgrounds from EU countries in Eastern Europe incl. Cyprus and other Eastern European countries is negatively correlated with average household income and all greenspace measures; but no significant associations are found with average property prices. These indicates that neighborhoods with a high percentage of residents belonging to the last two groups in Eastern Europe tend to have less available greenspace. The results are presented in Table 4.

Table 4. Bivariate analysis of neighborhood factors & % of residents from Eastern European counties

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9	10	11
1. Average Household Income (2011-2015)	1										
2. Average Property Price per sq. m. (2015)	.384**	1									
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1								
4. Natural Cover (%)	0.171	-.557**	.946**	1							
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1						
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1					
7. % of population from Western countries excl. Norway	.424**	.754**	-.389**	-.417**	-.319**	.357**	1				
8. % of population from Poland	-.289**	-.257*	-0.090	-0.013	-0.027	-.385**	-.284**	1			
9. % of population from EU countries in Eastern Europe and Cyprus	-.312**	0.050	-.440**	-.356**	-.287**	-.390**	0.070	.553**	1		
10. % of population from countries in former Yugoslavia	-.590**	-.507**	-0.167	-0.079	-0.134	-.720**	-.491**	.217*	.218*	1	
11. % of population from Eastern Europe (others)	-.262*	0.134	-.376**	-.312**	-.254*	-.345**	0.199	0.038	.389**	.327**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

6.3. **African Countries**

Table 5 shows the results of the analysis which includes all countries from the African region. The total population percentage of residents with African background is not associated with any greenspace measure. However, when the African region is further subdivided, it appears that the distribution of residents with a Somali background deviates from this trend. The results of analysis indicate that percentage of the population with a Somali background is negatively correlated with all greenspace measures: *Average Neighborhood Greenness* ($r = -.308$, $p<.01$), *Natural Cover* ($r = -.250$, $p<.05$), and *Tree Canopy Cover* ($r = -.295$, $p<.05$). However, no correlation was found in terms of property prices.

Table 5. Bivariate analysis of neighborhood factors & % of residents from African countries

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9	10	11
1. Average Household Income (2011-2015)	1										
2. Average Property Price per sq. m. (2015)	.384**	1									
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1								
4. Natural Cover (%)	0.171	-.557**	.946**	1							
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1						
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1					
7. % of population from Western countries excl. Norway	.424**	.754**	-.389**	-.417**	-.319**	.357**	1				
8. % of population from Sub-Saharan Africa	-.665**	-.622**	-0.080	0.043	-0.018	-.863**	-.475**	1			
9. % of population from Eritrea and Ethiopia	-.584**	-.565**	0.000	0.125	0.004	-.787**	-.477**	.841**	1		
10. % of population from Somalia	-.557**	-0.182	-.308**	-.250*	-.295**	-.583**	-0.171	.541**	.423**	1	
11. % of population from Africa (others)	-.604**	-.514**	-0.044	0.078	0.054	-.799**	-.337**	.815**	.825**	.486**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

6.4. Turkey and the Middle East

When the region of Turkey and the Middle East is further subdivided, the significant negative correlation between percentage of population with immigrant backgrounds and household income and property prices still holds; as well as the insignificant associations between all greenspace measures. Table 6 shows the results for the statistical analysis.

Table 6. Bivariate analysis of neighborhood factors & % of residents from Turkey and the Middle East

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9	10	11
1. Average Household Income (2011-2015)	1										
2. Average Property Price per sq. m. (2015)	.384**	1									
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1								
4. Natural Cover (%)	0.171	-.557**	.946**	1							
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1						
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1					
7. % of population from Western countries excl. Norway	.424**	.754**	-.389**	-.417**	-.319**	.357**	1				
8. % of population from Turkey	-.493**	-.611**	0.055	0.184	0.072	-.772**	-.456**	1			
9. % of population from Afghanistan	-.510**	-.587**	-0.004	0.106	-0.013	-.791**	-.473**	.707**	1		
10. % of population from Iraq	-.611**	-.548**	-0.111	-0.038	-0.118	-.818**	-.492**	.639**	.677**	1	
11. % of population from Iran	-.600**	-.566**	-0.141	0.002	-0.009	-.794**	-.347**	.612**	.601**	.653**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

6.5.South Asian Countries

The associations at the regional level also holds at the country level. However, it would appear that the percentage of the population with a Pakistani and Sri Lankan background is positively associated with the greenspace measures. No such association was found for percentage of population with an Indian background. Table 7 shows the results of the bivariate analysis.

Table 7. Bivariate analysis of neighborhood factors & % of residents from South Asian countries

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9	10
1. Average Household Income (2011-2015)	1									
2. Average Property Price per sq. m. (2015)	.384**	1								
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1							
4. Natural Cover (%)	0.171	-.557**	.946**	1						
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1					
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1				
7. % of population from Western countries excl. Norway	.424**	.754**	-.389**	-.417**	-.319**	.357**	1			
8. % of population from Pakistan	-.526**	-.759**	0.155	.306**	.217*	-.836**	-.511**	1		
9. % of population from Sri Lanka	-.451**	-.629**	0.110	.207*	0.034	-.696**	-.528**	.680**	1	
10. % of population from India	-.399**	-.422**	-0.076	0.046	0.021	-.616**	-0.173	.617**	.565**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

6.6.Southeast Asian and Oceanian countries

The Southeast Asian and Oceania region are further subdivided into two groups: Vietnam, and a second group which includes all other Asian countries including Oceania. The same associations can be seen between percentage of the population and average household income and property prices. However, only the second group is negatively associated with *Average Neighborhood Greenness* (r = -.229, p <.05). Table 8 shows the results of these associations.

Table 8. Bivariate analysis of neighborhood factors & % of residents from Southeast Asian and Oceanian countries

Correlation (Pearson's r)	1	2	3	4	5	6	7	8	9
1. Average Household Income (2011-2015)	1								
2. Average Property Price per sq. m. (2015)	.384**	1							
3. Average Neighborhood Greenness (NDVI)	.305**	-.467**	1						
4. Natural Cover (%)	0.171	-.557**	.946**	1					
5. Tree Canopy Cover (%)	0.163	-.498**	.868**	.907**	1				
6. % of population from Norway	.692**	.551**	.228*	0.054	0.135	1			
7. % of population from Western countries excl. Norway	.424**	.754**	-.389**	-.417**	-.319**	.357**	1		
8. % of population from Vietnam	-.617**	-.528**	-0.170	0.023	-0.086	-.829**	-.415**	1	
9. % of population from Asia (others, incl. Oceania)	-.403**	-.339**	-.229*	-0.091	-0.155	-.788**	-.213*	.604**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

7. Conclusions

The exploratory analysis reveals that there is a marked pattern of distribution of residents based on immigrant background across the neighborhoods of Oslo. The results of the analysis offer some support to the notion that unevenness exist in the city.

Neighborhoods where a high percentage of its residents are originally from Norway and other western countries tend to have higher average household incomes and higher property prices. However, in terms of greenspace availability, the former group is positively correlated with greenspace availability, while latter is negatively correlated. This indicates that although both groups tend to be over-represented in rich and expensive neighborhoods, immigrants from other western countries tend to live in neighborhoods with less greenspace, while the opposite is true for residents who are originally from Norway. Furthermore, the percentage of population with a background from non-western groups (with and without the inclusion of Eastern Europe) is negatively correlated with average household income and property prices.

The results regarding greenspace availability reveal marked differences as well, especially when the groups are divided into different regions, and further subdivided into different countries/group of countries. The highest concentration of residents with a background from Eastern Europe, Southeast Asia and Oceania, and Somalia tend to be in neighborhoods with less greenspace, while the opposite is true for residents with a Pakistani and Sri Lankan background. This highlights the importance of considering the distinctions between different immigrant groups when doing greenspace research.

The results of the exploratory analysis show a very interesting socio-spatial gradient in the distribution of population in Oslo. Neighborhoods with more ethnic Norwegians tend to have richer households, more expensive properties, and more available greenspace. This is the same for neighborhoods with a high percentage of residents from other western countries, but they tend to have less greenspace. And finally, the neighborhoods with a high concentration of non-western immigrant groups tend to have less affluent households, have lower property prices, and for some immigrant groups, less available greenspace.

Appendix 2. Reference for the neighborhood boundaries

Neighborhood	n	Reference for combination
UL:Smestad	115	Basic unit in Skøyen
UL:Bestum	72	Basic unit in Montebello-Hoff
UL:Ullerntoppen/Ullernåsen	55	Neighborhood value used
UL:Lysejordet	43	Basic unit in Ulleråsen, Ullernåsen data used
FR:Majorstua	126	Combined neighborhoods
NA:Tåsen/Berg	150	Tåsen neighborhood and Berg basic unit combined. Berg is inside Ullevål Hageby
NA:Ullevål/Blindern/Ullevål Hageby	125	Combination of basic units in the "Ullevål Hageby" neighborhood
NA:Nydalen/Storo	36	Combined basic units: Nydalen Vest, Nydalen Øst, Storo
NA:Maridalen/Solemskogen	20	Combined two basic units. Prominent outlier removed from the data set
NA:Korsvoll/Nordberg/Sogn	232	Combined neighborhoods (Korsvoll og Nordberg) and basic unit (Sogn)
SH:Lindern	17	Moved to Fagerborg (prior to data acquisition)
SA:Ila	12	Moved to Sagene (prior to data acquisition)
GL:Grünerløkka	174	Combined neighborhoods Grunerløkka vest og øst
BJ:Tonsenhagen	53	Tonsenhagen basic unit
BJ:Risløkka	93	Risløkka basic unit
BJ:Lofthus	10	Moved to Disen/Nordre Åsen (prior to data acquisition)
ST:Stovner/Tokerud	278	Combined neighborhood (Stovener) and basic unit (Tokerud)
ST:Furuset	15	Moved to Høybråten (prior to data acquisition)
GR:Kalbakken	77	Does not exist in the grunnkrets list. Between Rødvedt og Ammerud, Combined both neighborhoods
ØS:Abildsø, Manglerud, Ryen	212	Combined neighborhoods (Manglerud, Abildsø) and basic unit (Ryen)
ØS:Høyenhall, Rognerud	73	Combination of basic units in different neighborhoods: Høyenhall Nord og Sør (Godlia), Rognerud (Manglerud)
ØS:Oppsal, Skøyenåsen	216	Combination of basic unit Skøyåsen (in Oppsal) and neighborhood Oppsal
ØS:Godlia, Trasop, Hellerud	122	Combination of neighborhood (Godlia), and basic units Trasøp (Østre, Nordre, Søndre) and Hellerud
ØS:Bøler,Bogerud, Skullerud, Rustad	275	Combined neighborhoods of Bøler and Skullerud. Bogerud and Rustad is under the neighborhood Skullerud
NO:Karlsrud/Brattlikollen	100	Combined basic units
NO:Nordstrand/Ljan	446	Combination of neighborhoods Nordstrand og Ljan
SN:Holmlia	264	Combination of Holmlia Nord og Syd
SN:Dal-Brenna-Klemetsrud	54	Combined basic units (Dal and Brenna). Klemetsrud not found in the basic unit list, but inside Brena based on Google maps
Total	**3465**	**33.78% of N (10,255)**