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Master's Thesis

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Effects of *Area Developments* on the Ecological Quality of the Surrounding Green Space in the City of Zurich

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Summary

Cities all over the world are growing and have to find ways to accommodate all the new residents and to offer them a liveable city climate. The Swiss Federal Spatial Planning Act dictates densification before outward sprawl, but *denser* cities stand in conflict with *green* cities. The biggest Swiss city, Zurich, has various strategies to increase biodiversity as well as climate mitigation and adaptation whilst also getting denser. The instrument of *Area Developments* is one possibility for the city of Zurich to demand high quality densification from private landowners. Applying this instrument, owners of parcels bigger than $6000m^2$ are allowed to build denser and higher than the Communal Building and Zoning Regulation foresees if the overall impression of the buildings and their surroundings are "especially good" in return.

The instrument of *Area Developments* would have the possibilities to achieve several goals of the city at once: The "especially good design" could help the city to achieve high quality green spaces on private land whilst getting denser. This Thesis aims to analyse if the "especially good overall impression" of *Area Developments* already influences the ecological quality of the parcels it is applied to.

To compare the green spaces of the different parcels, a list of characteristics describing several aspects of the surroundings was developed. These characteristics were collected for 15 *Area Developments*, 15 parcels without the instrument, and a control group of 15 parcels. For each parcel, an aerial photograph from before the construction, and an aerial photograph of 2020 was studied, before inspecting the parcels on-site. In addition to the statistical analysis of this data, four experts were interviewed to inform the interpretation of the results.

The results show that the instrument of *Area Developments* significantly influences four out of 13 variables. These four variables are taken into account when the Building Committee assesses the building application, although architectural and spatial planning aspects have a higher priority. This led to a higher share of green space and more "natural greening" on parcels where the *Area Development* was applied. Additionally, the results suggest that overall, "mixed use" parcels have a lower ecological quality than "residential use" parcels.

The desire to build a green city should not only be the city's concern. Even without legally binding requirements, private landowners and developers should feel responsible for the future of the city of Zurich. Until this is fully the case, this Thesis suggests several policy recommendations for the city to have a bigger lever to implement high quality green spaces: The city of Zurich should define "ecological quality" and transform this definition into legal regulations. The current legal basis is scarce, making it difficult for the city to ask for high quality green spaces. The integration of ecological or environmental specialists in the evaluation panels should be the next step. It is necessary to have experts present when judging the "especially good overall impression" as well as for the development of high quality mixed use parcels. Additionally, collaborations with the different departments of the city as well as experts outside of the city administration should be increased. Such collaborations can improve the quality of a construction on several levels, as all the expertise is already included in the development process. All these adjustments help the city of Zurich to move into the direction of a city adjusted to the needs of the future residents.

Zusammenfassung

Städte auf der ganzen Welt stehen vor der Herausforderung, die wachsende Bevölkerungszahl zu bewältigen und den zukünftigen StadtbewohnerInnen ein lebenswertes Umfeld zu bieten. Das Schweizerische Bundesgesetz über die Raumplanung sieht eine Siedlungsverdichtung nach innen vor, allerdings steht Dichte häufig im Konflikt mit Grünflächen. Zürich, die grösste Stadt der Schweiz, hat mehrere Strategien um neben einer erhöhten Dichte auch eine erhöhte Biodiversität sowie mehr Klimaschutz und Klimaanpassung zu erreichen. Das Instrument der *Arealüberbauung* ist eine Möglichkeit für die Stadt Zürich von privaten GrundeigentümerInnen qualitativ hochwertige Verdichtung zu verlangen. Parzellen, die grösser als 6000m^2 sind, dürfen dichter und höher bebaut werden, als es die Bau- und Zonenordnung vorsieht, wenn im Gegenzug der Gesamteindruck der Gebäude und ihrer Umgebung "besonders gut" ist. Das Instrument der *Arealüberbauung* ermöglicht es, mehrere Ziele der Stadt gleichzeitig zu erreichen: Die "besonders gute Gestaltung" könnte dazu beitragen, qualitativ hochwertige Grünflächen auf privatem Grund zu schaffen und gleichzeitig die Bebauung verdichten. Ziel dieser Arbeit ist es zu analysieren, ob der "besonders gute Gesamteindruck" von *Arealüberbauungen* in den vergangenen Jahren bereits die ökologische Qualität der Parzellen beeinflusst hat.

Um die verschiedenen Grünflächen zu vergleichen, wurde eine Liste von Merkmalen entwickelt, die verschiedene Aspekte des Aussenbereichs von Parzellen beschreiben. Diese Merkmale wurden auf 15 *Arealüberbauungen*, 15 Parzellen ohne das Instrument, und einer Kontrollgruppe von 15 Grundstücken erhoben. Für jede Parzelle wurde ein Luftbild aus der Zeit vor dem Bau und ein Luftbild aus dem Jahr 2020 betrachtet, und zusätzlich wurde jede Parzelle vor Ort besichtigt. Neben der statistischen Analyse dieser Daten wurden vier Experteninterviews geführt, um eine qualitative Grundlage zur Interpretation der Ergebnisse zu schaffen.

Die statistischen Resultate zeigen, dass das Instrument der *Arealüberbauung* vier von 13 Variablen signifikant beeinflusst. Diese vier Variablen werden bei der Beurteilung des Baugesuches durch das Baukollegium beachtet, obwohl architektonische und raumplanerische Aspekte eine höhere Priorität haben. Das hat bewirkt, dass der Anteil Grünfläche und der Anteil an natürlichem Grün auf Parzellen mit dem Instrument der *Arealüberbauungen* höher sind als bei herkömmlichen Überbauungen. Die Resultate deuten zudem darauf hin, dass Parzellen mit Mischnutzung insgesamt eine geringere ökologische Qualität aufweisen als Grundstücke mit reiner Wohnnutzung.

Das Ziel einer grüneren und lebenswerteren Stadt sollte nicht nur ein Anliegen der Stadt sein. Auch ohne gesetzliche Vorgaben sollten private GrundeigentümerInnen und EntwicklerInnen sich für die Zukunft der Stadt Zürich verantwortlich fühlen. Solange dies noch nicht immer der Fall ist, braucht die Stadt gesetzliche Mittel und Wege um eine erhöhte Grünflächenqualität zu erreichen. Aus dieser Arbeit gehen die folgenden strategischen Massnahmen hervor: Die Stadt Zürich braucht eine Definition von "ökologischer Qualität", die anschliessend in gesetzliche Regelungen zur Raumplanung übersetzt werden muss. Die heutige Rechtsgrundlage ist bescheiden, was es der Stadt erschwert, eine hohe Qualität an Grünflächen zu fordern. Ein nächster Schritt ist die Einbeziehung von ÖkologInnen oder UmweltspezialistInnen in die Bewertungsgremien. Bei der Beurteilung des "besonders guten Gesamteindrucks" sowie bei der Entwicklung von hochwertigen gemischt genutzten Grundstücken ist die Anwesenheit von ExpertInnen notwendig. Zusätzlich sollte die Zusammenarbeit mit den verschiedenen Abteilungen der Stadt sowie mit ExpertInnen außerhalb der Stadtverwaltung gestärkt werden. Solche Kooperationen können die Qualität eines Bauvorhabens auf vielen Ebenen verbessern, da das gesamte Fachwissen bereits im Entwicklungsprozess miteinbezogen wird. Diese Veränderungen könnten Zürich helfen, den bebauten und unbebauten Lebensraum der Stadt an die Anforderungen der zukünftigen BewohnerInnen anzupassen.

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List of Abbreviations

AfS Department for City Planning of the City of Zurich

AIC Akaike Information Criterion

ANOVA Analysis of Variance

BZO Communal Building and Zoning Regulation of the City of Zurich

CSP Communal Structure Plan

GIS Geographic Information System

GSZ Department for Green Spaces of the City of Zurich

MLR Multiple Linear Regression

PBG Cantonal Planning and Building Act

PC Principal Component

PCA Principal Component Analysis

RDD Regression Discontinuity Design

SHDI Shannon Diversity Index

UGS Urban Green Space

UHI Urban Heat Island

UN United Nations

List of Translations

English	**German**
Area Developments	*Arealüberbauungen*
Building application	Baugesuch
Building Committee	Baukollegium
Building inspection	Bauabnahme
Building permission procedure	Baugenehmigungsverfahren
Cadastral Surveying	Amtliche Vermessung
Communal Structure Plan (CSP)	Kommunaler Richtplan
Department for City Planning	Amt für Städtebau (AfS)
Department for Green Spaces	Grün Stadt Zürich (GSZ)
Design Plan	Gestaltungsplan
Environmental Masterplan	Masterplan Umwelt
Green Book	Grünbuch
Sectoral Plan on City Trees	Fachplanung Stadtbäume
Sectoral Plan on Heat Reduction	Fachplan Hitzeminderung
Special Land Use Plan	Sondernutzungsplan
Unit for Architecture and Urban Space	Fachbereich Architektur und Stadtraum
Unit for Area Developments and Planning	Fachbereich Arealentwicklung und Planung
Unit for Open Space Consulting	Fachstelle Freiraumberatung
Utilisation Rate	Nutzungsziffer
Zoning Plan	Zonenplan

1 Introduction

The world's population has been growing extensively in the 20th century and is projected to continue growing until at least the end of the 21st century (Roser, 2013). The United Nations (UN) expect that cities will have to accommodate most of this population growth, as 68 percent of the world's population is expected to live in urban areas by 2050, up from 55 percent in 2018 (UN, 2018). People living in cities still want to have a connection to nature and use it as a recreational space. This became especially important during the Covid-19 pandemic in the years 2020 and 2021, when the restricted mobility resulted in a high demand for green spaces in close proximity (Day, 2020; Kleinschroth and Kowarik, 2020; Venter et al., 2020). Due to densification and the increasing population, there is a high pressure of use on the existing Urban Green Space (UGS) (Arnberger, 2012). It is therefore important to create further green spaces while providing living and housing spaces for the growing population.

In Switzerland, densification and development of already built areas are prime goals of spatial planning since the revision of the Federal Act of Spatial Planning in 2014 (ARE, 2015). For 2040, the most probable scenario predicts a population of 515'600 inhabitants for the city of Zurich, while its population was 434'008 in 2019 (Stadt Zürich, 2020a). This corresponds to a population growth of about 18%. Instead of claiming agricultural or recreational land for new buildings to accommodate this growth, built areas should be densified. The existing potential according to the Zoning Plan should be fully used and at appropriate locations it should be allowed to build even denser (ARE, 2015).

Inward development conflicts with the establishment of green infrastructure for ecology, climate mitigation, and climate adaptation (Aronson et al., 2014; Haaland and van Den Bosch, 2015). Besides getting denser, cities need to provide open and green spaces to allow for agreeable surroundings and a high quality of life. It will be necessary to implement green infrastructure in a widespread manner to achieve cooler cities in the future, as greening can reduce Urban Heat Islands (UHIs) through transpiration (IPCC, 2022; Norton et al., 2015; Rahman et al., 2020). Besides reducing the temperature of the city, UGSs deliver ecological qualities through their natural attributes such as plant diversity, flower density, or canopy cover (Hunter and Luck, 2015). The planning and design of multifunctional green spaces serving social functions (e.g., as a place to meet the neighbourhood), ecological functions as mentioned above, and economic functions (e.g., upgrading of nearby housing) will be necessary in the future to ensure the compatibility of inward development with a liveable urban climate (ARE, 2015; Niemelä et al., 2011; Stadt Zürich, 2022b). This Thesis will primarily focus on the ecological functions of the green spaces.

The city of Zurich has specific goals concerning open and green spaces: In 2020, the city published the "Sectoral Plan on Heat Reduction"[1]. It serves as the baseline to design green and open spaces as well as streets and other public places adapted to the new climate (Stadt Zürich, 2020b). Both green spaces and settlement structure are "areas of action" in the "Sectoral Plan on heat reduction". Other strategic documents such as the "Environmental Masterplan 2017-2020"[2] or the new "Sectoral Plan on City Trees"[3] all point in a similar direction (Stadt Zürich, 2016, 2022a).

An important question is thus how to connect inward development and ecological quality. The *Area Development*[4] is a spatial planning instrument of the city of Zurich that intends to promote inward development. It is defined in §69ff of the Cantonal Planning and Building Act[5]

[1]German: "Fachplanung Hitzeminderung"
[2]German: "Masterplan Umwelt 2017-2020"
[3]German: "Fachplanung Stadtbäume"
[4]German: "Arealüberbauung"
[5]German: "Kantonales Plan- und Baugesetz [des Kanton Zürich]"

(LS700.1; hereinafter PBG) and further specified in Article 8 of the Communal Building and Zoning Regulation of the City of Zurich (BZO)[6]. It allows landowners of parcels bigger than 6000m^2 to build with a higher utilisation rate than dictated by the Zoning Plan. In return, the §71 of the PBG states that "the buildings and their surroundings must be designed especially well, as well as equipped appropriately"[7]. For the evaluation of the "especially good design" the "location, purpose, extent and design of the surrounding facilities"[8] (PBG §72 lit. c) must be considered.

The law thus refers not directly to the ecological quality, but has a strong social aspect. To gain the full density-bonus, the buildings must comply with 'Minergie' standards (Article 8 Section 8 BZO). This passage indicates that the city of Zurich wants this instrument to contribute to the climate mitigation goals. It is desirable that nature and climate mitigation profit from the "good design" as well.

The instrument of *Area Developments* offers a big opportunity to the city of Zurich to influence the building politics of private builders. *Area Developments* allow for demanding more high quality structures than building applications without this instrument (GSZ, 2022). The Building Committee evaluating the *Area Development*-projects on the "especially good overall impression" takes aspects of the green spaces into account as well (AfS, 2022a). It is necessary to examine if these endeavors are successful and the requirements are implemented in reality and visible in higher ecological quality of *Area Developments*. This Thesis offers a scientific approach to these questions and forms a foundation on which further developments of spatial planning instruments can build. It aims at answering the following main research question:

> *What impact does the instrument of* Area Developments *have on the ecological quality of the green spaces in the city of Zurich?*

To answer this question, the following subquestions need to be answered first:

1. *How can ecological quality be defined?*
2. *Which other aspects could influence the ecological quality of parcels?*
3. *How is the ecological quality of* Area Developments *evaluated in the building permission procedure?*

A list of characteristics of green spaces was compiled to define ecological quality and therefore answer the first subquestion. The list of characteristics includes aspects of parcels that do not directly describe the ecological quality but draw a complete picture of the state of a parcel. These additional characteristics help to answer the second subquestion. Lastly, expert interviews were conducted to understand the building permission procedure of the *Area Developments* and to inform the interpretation of the quantitative results of the statistical analysis.

The Policy Impact Analysis of this Thesis can contribute to the further development of spatial planning policy instruments in the city of Zurich. The Thesis additionally contributes to the discussion about the conflict between densification and green space development and suggests options to better include ecological quality into spatial planning.

[6] German: "Kommunale Bau- und Zonenordnung [der Stadt Zürich]"

[7] German: "Die Bauten und Anlagen sowie deren Umschwung müssen besonders gut gestaltet sowie zweckmässig ausgestattet und ausgerüstet sein."

[8] German: "Lage, Zweckbestimmung, Umfang und Gestaltung der Umgebungsanlagen"

Following the introduction, Section 2 contains a literature review summarizing the relevant existing literature about densification, biodiversity, and its functions in the city. Section 3 describes the background of the Thesis and states the hypothesis that needs to be tested. This is followed by Section 4 about the material used and the methods applied. Section 5 is divided into qualitative and quantitative results, summarizing the results of the statistical analysis (Section 5.1) and the results of the expert interviews (Section 5.2), respectively. Section 6 first discusses and interprets the results, before critically reflecting on the material and methods. Finally, Section 7 offers policy recommendations (Section 7.1) as well as an outlook (Section 7.2) into future research concerning spatial planning in general as well as the *Area Developments* in the city of Zurich specifically.

2 Literature Review

The discipline of urban ecology emerged in the 1990s as cities grew and the need to better understand the link between ecology and the human influence arose (McDonnell and MacGregor-Fors, 2016). The scientific discussion about ecological quality of dense urban areas can roughly be classified into (i) densification and its climatic effects, (ii) biodiversity in the city, and (iii) functions of biodiversity in the city (social, ecological, health). This literature review gives a brief overview over these three categories and their implications for this Thesis.

Densification and its Climatic Effects. One of the most pressing issues concerning densification in cities is the heating effect of sealed streets and concrete buildings, which threatens the health of the population (Heaviside et al., 2017; Lemonsu et al., 2015). Aram et al. (2019) reviewed several articles covering the "Cool Island Effect" of UGS that all agree that UGS can help to reduce UHI effects. A widespread implementation of green infrastructure would be required to substantially reduce the UHI of a whole city (Norton et al., 2015). It was shown that green spaces cool especially well if they are complex, i.e., have several different types of structures, and contain bodies of water (Du et al., 2017). Park et al. (2017) additionally concluded that type, structure, and size of green spaces affect the degree of cooling. They found that diverse types of green spaces would reduce UHIs more than green spaces comprised of simple structures.

To study the effects of green spaces on UHIs it is necessary to define scientific measures to compare different cities and there are different approaches to quantify these effects. A common measure is "green space per capita"; the goal of the city of Zurich is $8m^2$ per inhabitant and $5m^2$ per person working in Zurich (Stadt Zürich, 2019a). Yao et al. (2014) provide the Effective Green Equivalent which corrects the total area of green space for quality and accessibility. There are more studies providing concepts about the ecology of urban areas, green space characteristics of a whole town, or the hemeroby of cities, which measures the amount of human influence on nature, but single green spaces in particular are rarely studied (Stein and Walz, 2012; Teimouri and Yigitcanlar, 2018; Werner, 2011).

Biodiversity in the City. Complex green spaces reduce UHIs and additionally improve the ecological quality and biodiversity by offering many different habitats for various organisms (Fontana et al., 2011; Sattler et al., 2010). The biodiversity of UGSs is a widely studied topic. The diversity of habitats and the microhabitat heterogeneity appear to be the most decisive factors for biodiversity, defined as species richness (Nielsen et al., 2014). Bräuniger et al. (2010) found that landscape structure and geological diversity are key factors for explaining biodiversity. In this Thesis, landscape structure and habitat diversity are the most important factors serving as proxies for biodiversity, as all the parcels analysed constitute of the same geology. The application of this proxy is further verified by the findings of several studies: Habitat diversity serves as an indicator for species richness and species richness serves as a useful indicator for biodiversity of vascular plants, ground dwelling arthropods and flying insects (Home et al., 2019; Sattler et al., 2010; Whitford et al., 2001). Despite urban growth reducing bird distribution, urban environments are still biodiverse (Nielsen et al., 2014; Sushinsky et al., 2013). Nielsen et al. (2014) found that parks are among the most species rich green spaces in cities.

Loram et al. (2008) studied private gardens and found that the complexity of gardens correlated with their area in five cities across the United Kingdom. They concluded that garden area is the key factor in determining the internal composition of domestic gardens. This is not only true for green spaces but for cities as a whole: the total species number was positively correlated with city size (Niemelä et al., 2011).

When analysing biodiversity, it is important to distinguish between native and exotic species. McDonnell and MacGregor-Fors (2016) found that cities with at least 30% native vegetation cover had less local plant extinction than cities with less native vegetation cover. The presence of natural vegetation cover is important for maintaining bird and plant populations and the distribution of the natural vegetation cover explains the variation in the extinction rate of plants in urban areas (Aronson et al., 2014; Hahs et al., 2009). Therefore, it is important to chose the right species for the right places when creating a new UGS (Vogt et al., 2017).

Functions of Biodiversity in the City. Biodiversity and green spaces provide different services to people, e.g., climate mitigation as mentioned before, but also health benefits, food sources, or recreational quality. "Quality of your Environment" is one of eleven variables that make up the "Better Life Index" of the Organisation for Economic Co-operation and Development (OECD, 2020). Home et al. (2019) support this calculation as they found that UGSs contribute to the perceived quality of urban landscapes and to the quality of life of urban residents. High biodiversity is beneficial for city residents in general as it offers many different experiences and improves recreation (Sattler et al., 2010). The maintenance of urban green spaces has therefore at least two simultaneous goals: the recreation of residents as well as the protection of species and habitats (Bräuniger et al., 2010).

For green spaces to fulfill their potential of ecological functions, there are several preconditions. Loram et al. (2008) found that the ecological functions provided by domestic gardens depend critically on their configuration and composition. Smith et al. (2005) state that garden size is enormously important when determining garden composition: larger gardens contain more landcovers and are more likely to contain trees taller than two meters. This is just one of many examples for the trade-off between big green spaces and densification. High amounts of sealed surfaces limit habitat space for many species (Bräuniger et al., 2010). This then influences the ecosystem functions, e.g., climatic energy exchange and hydrology, as surface cover is an important determinant for ecosystem processes in cities (Niemelä et al., 2011). Increasingly, urban ecologists are integrating socioeconomic processes, urban management, planning and design in their studies (McDonnell and MacGregor-Fors, 2016). This is necessary as the current density of species in cities and the loss of species can best be explained by anthropogenic features, such as landcover or city age, rather than by non-anthropogenic features, such as geography, climate or topography (Aronson et al., 2014). However, human activity in cities creates and maintains a variety of habitats for animals and plants, and is thus not exclusively bad (Bräuniger et al., 2010).

3 Background

In November 2021, the electorate of Zurich accepted the new Communal Structure Plan (CSP)[9] with a clear verdict of 61.2 percent yes-votes (Stadt Zürich, 2021c). The CSP draws a vision for the city for the year 2040 (Stadt Zürich, 2021a): It designates areas that are suitable for high quality densification and areas for public green spaces. Additionally, there are guidelines on how to create a socially and environmentally acceptable city development. According to the CSP the densification should be focused in "Zürich Nord/Leutschenbach/Glattal", the Airport-Region and "Zürich-West/Altstetten/Limmattal" (Stadt Zürich, 2021b). These are all former "outskirts" of the city that are now part of supraregional development areas. The CSP specifies that the network of habitats with high ecological quality should be preserved, improved and expanded (Stadt Zürich, 2021b).

Besides the "Sectoral Plan on Heat Reduction", which was described in Section 1, the city of Zurich has other strategic documents defining specific goals concerning open and green spaces: The "Environmental Masterplan 2017-2020" states an area of action called "Connecting Inward Development with High Environmental Quality" (Stadt Zürich, 2016). It includes green and open spaces, biodiversity, local climate, soundscapes, public transport connections as well as bike- and footpaths. Another important document is the "Green book" of the city of Zurich, which includes all the important information about the goals for the different types of green spaces in the city, maintenance guidelines and information about cross-sectional topics such as climate, biodiversity, recreation, or soil (GSZ, 2019). The new CSP together with the non-binding strategies of the city of Zurich build on the aforementioned literature and show the will of the city to act for climate adaptation and mitigation as well as for more biodiversity.

A city has only limited power to influence the building action of private landowners (Gerber et al., 2018). According to Hengstermann and Hartmann (2018), there are four categories of policy instruments to manage the scarcity of land: regulating land uses through public policy without impacting property rights, steering land uses through regulation and thereby impacting property rights, redefining property rights to steer land uses, and redistributing property rights to steer land uses. The first category is the only one that does not impact property rights and is therefore the least invasive, but tends to be the one with the least influence. The Communal Structure Plan as well as the *Area Developments* are examples for this category.

The instrument of *Area Developments* is similar to the instrument of extended land service tax in Switzerland, which demands taxes from landowners for land services from which they profit (Viallon, 2018). If the instrument of *Area Developments* is applied, landowners are allowed to build with a higher density than the Zoning Plan foresees. In return, the design of the whole building-complex needs to be "especially good", for the public space to gain quality. The landowners pay for their additional profit by investing more thought, time, and money into the design of the whole project.

Considering the goals of the city of Zurich concerning climate and biodiversity, it is surprising that these are not explicitly included in a spatial planning instrument such as the *Area Developments*. *Area Developments* offer a big opportunity to include privates into the endeavour to achieve a greener city. The hypothesis that needs to be tested to answer the research question is deducted from literature and the goals of the city of Zurich as a whole:

> *The green spaces of parcels with* Area Developments *have a higher quality than the green spaces of parcels without the instrument of* Area Developments.

[9] German: "Kommunaler Richtplan"

4 Material and Methods

4.1 Material

Spatial data of the city of Zurich was utilized to define the different parcels for the study. The main focus was on the data-set "Area Developments", which contains all the *Area Developments* since 1999, as well as older versions of the spatial planning instrument. Additionally, the "Cadastral Surveying"[10] of the city of Zurich was used. Additionally, a data-set about the age of the buildings and the Zoning Plan were consulted. Aerial photographs of Zurich from several years served as the baseline for the first analysis of the parcels (1999, 2002, 2007, 2010, 2013, 2016, 2020). A digital surface model of the year 2019 was used to detect the height of the trees. All the data-sets with the corresponding sources are listed in Table 1. Google Earth and Google Street View from Google Maps were used to find additional information on the buildings, such as the number of floors.

Table 1: Spatial data-sets used in the analysis.

Data-set	**Source**
Area Developments	©City of Zurich
Cadastral Surveying[10]	©Canton of Zurich
Age of buildings	©Canton of Zurich
Orthophotos (swissimage) 1999, 2002, 2007, 2016	©Remote Sensing @ WSL
Orthophotos (swissimage) 2010, 2013, 2020	©City of Zurich
Digital surface Model 2019	©Remote Sensing @ WSL
Zoning Plan	ÖREB-Kataster @ Canton of Zurich
Google Maps	https://www.google.ch/maps
Google Earth Pro	Google Earth Pro (Version 7.3.4.8248)

4.2 Methods

An initial analysis of the spatial data showed that there are sufficient parcels available in the city of Zurich for the present study. The parcels on which the instrument of *Area Developments* was applied were taken from the data-set "Area Developments" of the city of Zurich. Areas without the *Area Development*, but with the appropriate size (5000m^2 to 7000m^2, see 4.2.1) were retrieved from the "Cadastral Surveying"[10]. On all the areas, the age of the buildings was assessed to only compare buildings that were built after 1999, as the newest revision of the instrument *Area Developments* stems from this year. The specific areas for the investigation were chosen following the method of Regression Discontinuity Design (RDD), described in Section 4.2.1. To analyse the ecological quality, a catalog of characteristics of green spaces was compiled. Following this protocol, the data about the parcels was collected with a Geographic Information System (GIS) analysis and an on-site inspection. The data was analysed using Multiple Linear Regression (MLR) Techniques followed by expert interviews to inform the discussion of the Thesis.

4.2.1 Regression Discontinuity Design

The Thesis uses the method of RDD, which is applicable to investigate the effects of applying a certain policy or treatment to a part of the analysed objects based on a fixed threshold (Dunning, 2012). It is possible to study the effect of this policy when comparing the objects that are right below and right above the threshold value. In this Thesis, the threshold is the parcel size of 6000m^2. The RDD assumes that parcels just below and just above this size have the same prerequisites

[10] German: "Amtliche Vermessung"

Table 2: Categories of parcels to be analysed.

	With ***Area Development***	**Without** ***Area Development***
5000m^2 to 6000m^2	-	Without Policy Instrument (Group 2)
6000m^2 to 7000m^2	With Policy Instrument (Group 1)	Control Group (Group 3)

for future development. The only difference between them is the application of the instrument of *Area Developments* on parcels above the threshold. This design allows studying the effect of the instrument of *Area Development* on the ecological quality of the parcels. Parcels of three different groups will be analysed (Table 2):

Group 1 With Policy Instrument: Parcels between 6000m^2 and 7000m^2, built with the instrument of *Area Developments* to analyse their ecological quality.

Group 2 Without Policy Instrument: Parcels between 5000m^2 and 6000m^2, built after the regulations of the BZO to compare to Group 1 to analyse the differences between the parcels with and without the instrument.

Group 3 Control Group: Parcels between 6000m^2 and 7000m^2, built after BZO to control for the assumption that the size itself does not make a difference concerning the ecological quality as all the parcels are close to 6000m^2.

It is necessary to decide on a bandwidth in which the areas are assumed to have the same preconditions. In this Thesis, a bandwidth of 5000m^2 to 7000m^2 was taken into account and it was decided to work with a sample size of 15 parcels per group.

In the statistical analysis, the assumption that Group 2 and Group 3 are not significantly different was tested with a Kruskall-Wallis Test, since it can be applied to ordinal as well as interval-scaled variables (Kruskal and Wallis, 1952; UZH, 2020). The Kruskall-Wallis Test controls for the Null-Hypothesis "The two groups are the same". If the p-value of the test is significant ($\alpha < 0.1$), the Null-Hypothesis can be rejected, which means that the groups are significantly different from one another. If the Null-Hypothesis could not be rejected, the RDD-assumption was considered to be valid as the groups were therefore not significantly different from one another.

It is standard practise to show the results of a Regression Discontinuity Design in RDD-plots. They show the data points around the threshold and the discontinuity becomes visible if one is present. Additionally, smoothness-plots are shown in standard practice RDD-analyses (Tur-Prats and Valencia Caicedo, 2020). These show that the chosen parameter is the only one that exhibits this discontinuity and all the covariates do not. It was not possible to comply with this standard practice in this Thesis, as all the covariates are ordinal-scaled, which makes them unsuitable for RDD-plots.

4.2.2 Parcel Selection and Data Collection

The selection of parcels was limited by their availability. For Group 1 (between 6000m^2 and 7000m^2, with *Area Development*), 24 parcels were available. Out of these, six were not eligible because no building activity was visible on the aerial photographs or they belonged to a bigger building project. Three further parcels were in the building process in 2020, which made the analysis of the aerial photograph of 2020 impossible. Therefore, 15 parcels were left for the analysis.

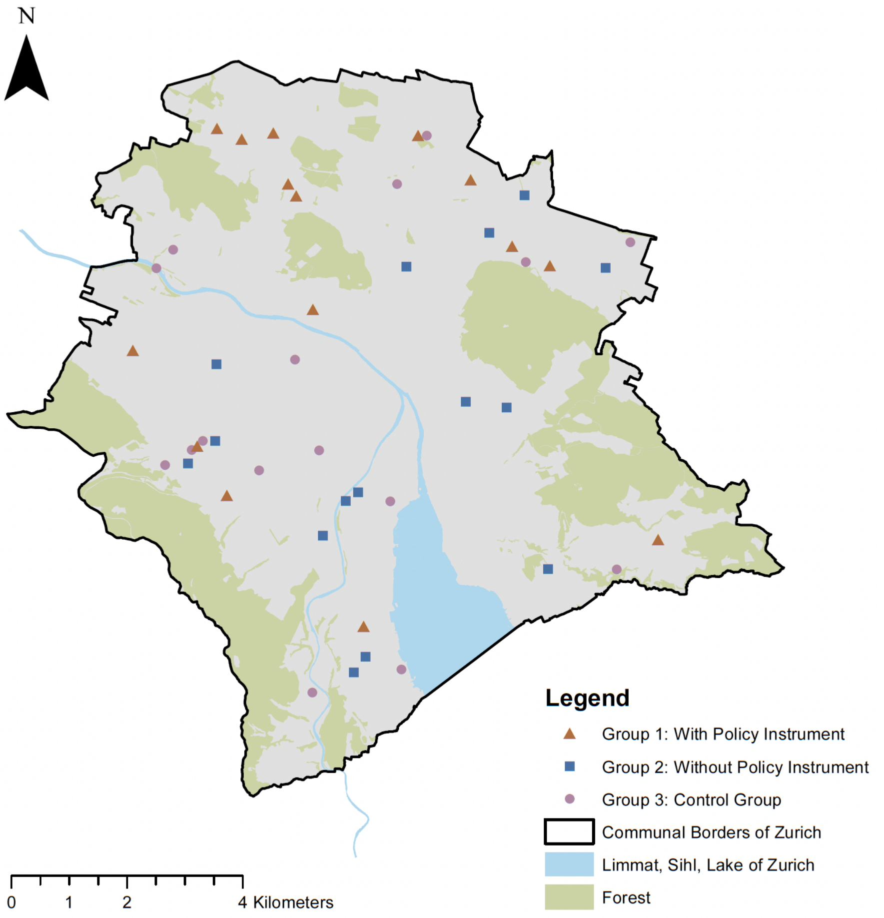
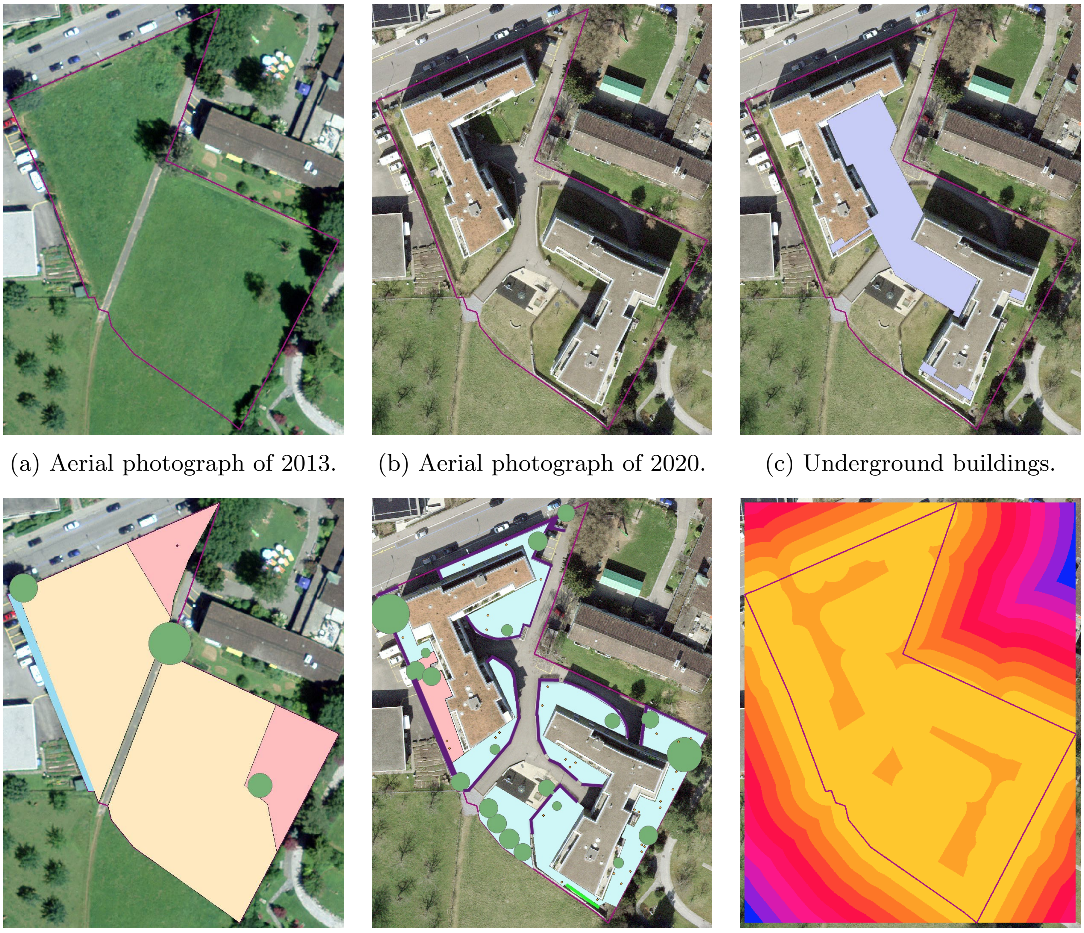


Figure 1: Distribution of parcels in the communal borders of the city of Zurich. Compiled on the basis of spatial data-sets of ©City of Zurich and ©Canton of Zurich.

Group 2 (between 5000m^2 and 6000m^2, without *Area Development*) had the biggest sample size initially. There are 85 parcels with the corresponding size that have been built since 1999. Out of these, 51 had to be dropped as they were either a street parcel, the buildings of the parcel were combined with buildings on the neighbouring parcels or no building activity was visible. Of the remaining 34, another 15 were not eligible, as they were only partially built on, or part of a bigger development area. Out of the remaining 19 parcels, 15 were chosen for the analysis based on their location and the state before the transformation. The parcels should be distributed across the whole city and both parcels with and without buildings on the aerial photograph before the new construction should be present in the sample. After the analysis of the aerial photographs and the on-site analysis, two additional parcels of Group 2 had to be replaced. One of these parcels was wildly overgrown, it would have been impossible to count the trees and a new category of "Forest" would have been necessary. This would knowingly have led to the creation of an outlier. The other parcel that was omitted after the on-site inspection was an area with exclusive access, which is not in the sense of *Area Developments* granting access to all tenants if not to the broad public.

Group 3 (between 6000m^2 and 7000m^2, Control Group) consisted of 66 parcels after the initial search. In the first elimination round, 42 parcels were rejected due to the same reasons as mentioned above. Seven more parcels had to be discarded due to being part of bigger development areas or only being partially built on. Out of the remaining 17 parcels, 15 were chosen with the same reasoning as for Group 2. The spatial distribution of the 45 parcels of the analysis is displayed in Figure 1.

After the selection, the aerial photographs of the parcels from before the transformation and from the year 2020 were analysed. The factors of the characteristics list described in Section 4.2.3 were considered for the analysis. All the spatial analyses were computed on the GIS software ArcMap 10.0 of ESRI. The parcel sizes were taken from the data-set "Cadastral Surveying" (state of 2020). The footprint of the buildings were measured from the aerial photographs. The different types of greening, as well as trees and bushes were measured by drawing polygons for each characteristic onto the aerial photographs. Single bushes as well as fountains or other water features were mapped as point features. For the analysis of the year 2020, the underground buildings were taken from the data-set "Cadastral Surveying". The different layers of this analysis are shown for one parcel in Figure 2.



(a) Aerial photograph of 2013. (b) Aerial photograph of 2020. (c) Underground buildings.

(d) All the structures of 2013. (e) All the structures of 2020. (f) Euclidean Distance.

Figure 2: Example pictures of GIS-analysis, Object-No. 17. In image (d), blue = fallow vegetation, orange = agricultural field, rosé = meadow, green = trees, red point on top = bush. In image (e), blue = lawn, rosé = meadow, light green = bush row, purple = hedge row, dark green = trees, orange points = bushes. In image (f), the brighter the lower the *Euclidean Distance*.

After the GIS-analysis, the parcels were analysed on-site noting the tree species and some more detailed information, such as the presence of undesirable species or a clear distinction between lawn, meadow and fallow vegetation, that could not be seen in the aerial photographs. The characteristics are described in more detail in Section 4.2.3. The on-site inspection was recorded in the form of map sketches, in which all the different characteristics were noted, as well as with a quantitative protocol which can be found in Appendix A. The sketch was drawn on a basic map of each parcel taken from the "Cadastral Surveying". This information was then transcribed into GIS-layers to measure the dimensions of the different polygons. These on-site-measurements were the ones taken for the analysis for most characteristics. The values of the GIS-analysis of the aerial photograph of 2020 were helpful for the digitalization of the on-site protocols, as many of the polygons could be copied and adjusted. Several variables were directly calculated in the GIS or from data of the GIS:

- *Shannon Diversity Index (SHDI)*: The total sizes of each single charachteristic were taken and their share of the whole parcel was calculated. Then the SHDI was calculated using the following formula:
$$SHDI = -\sum_{i=1}^{m}(P_i \ln(P_i))$$
where P_i is the proportion of the landscape occupied by patch type i and m is the number of patch types.
- *Edge Density Index*: A buffer was compiled around the point features of the single bushes resulting in an area of $2m^2$ for each bush. Then, the trees, single bush buffers, hedge rows and bush rows were combined into one layer. The edge of the polygons of the combination of all these characteristics was then divided by the whole area of the parcel.
- *Number of Patches*: The *Number of Patches* for each type of characteristic was taken from the GIS and all the characteristics were summed up to have the number of patches per parcel. These were then standardized to get the *Number of Patches* per $1000m^2$ of parcel area.
- *Mean Euclidean Distance*: The combined bush-tree-layer from the *Edge Density Index* was combined with the *Green Share* layer. The *Green Share* layer contains all the patches that are considered to be part of the green space of the parcel. The patches with bushes and trees were assigned the number 2, whereas the green space patches were assigned the number 1. Then the "Euclidean Distance" was calculated for the whole parcel through the GIS-command "Euclidean Distance". From this new "Euclidean Distance"-layer, the mean value was taken for the *Mean Euclidean Distance* of the parcel.

4.2.3 Characteristics of Green Space

A list of characteristics for the definition of ecological quality was defined, building on the Master's Thesis of Wild (2013). The list of characteristics was reduced according to the discussion of Wild (2013) and extended according to a literature search (Aronson et al., 2014; Bräuniger et al., 2010; Cornelis and Hermy, 2004; Davies et al., 2009; Douglas and Philip, 2014; Grote et al., 2016; Helletsgruber et al., 2020; Home et al., 2019; Loram et al., 2008; McDonnell and MacGregor-Fors, 2016; Niemelä et al., 2011; Rahman et al., 2020; Sattler et al., 2010; Smith et al., 2005; Vogt et al., 2017). Not all the characteristics were measured in each of the three analyses. The overview of all the collected characteristics can be found in Appendix B. This list and the following reduction can be counted as the response to the first subquestion of this Thesis: *How can ecological quality be defined?*

The 40 collected characteristics were reduced to 19 dependent variables that are listed in Table 3. These variables can be categorised into four categories: parcel structure, biodiversity, climatic effect and design. These categories help to structure the discussion as they allow to group the high number of dependent variables. Reducing the variables was achieved by combining and neglecting some. Variables were combined on the basis of a correlation analysis and a Principal Component Analysis (PCA). Right at the start of the variable reduction, *Walls* and *Water* were neglected as the data collection showed that only very few parcels had features of either category. The share of green space was kept as an important variable (*Green Share*). *Green Share Without Built Underground* and *Green Flat Roof Share* were kept as well.

The three variables for bushes and hedges were combined into one *Bush Variable* as a weighted sum. The hedges always had a weight of 1, whereas the bushes and bushrows had either a weight of 2 or 3; 2 if there were four or less species present, 3 if there were more than four species present. The hedges were counted as less valuable because they were categorized as hedges if they were less natural in the field, meaning if they were cut regularly and, e.g., used as fences. There is a second variable for the bushes accounting for the presence or absence of undesirable species (*Undesirable Species*), which are defined as invasive species that are threatening biodiversity of native species. In particular, the occurrence of the following four specific species was checked: *Prunus laurocerasus, Thuja sp., Cotoneaster sp., Buddleja davidii*. These species occur frequently in domestic gardens and impede native plant diversity.

For the greening, six variables were measured and a PCA was conducted (Appendix C). It showed that the greening-variables could be reassembled into *Natural Greening* (meadow, fallow vegetation) and *Artificial Greening* (lawn, garden, bare ground, and agriculture).

The tree characteristics had to be reassembled as well. The variable *Number of Trees* remained. To account for the age difference of the parcels, the variable *Number of Trees with Growing Potential* was kept in the analysis. This variable is an expert judgement expressing how many trees have the potential to grow 50 years old based on their distance to each other. Both the *Number of Trees* as well as the *Number of Trees with Growing Potential* were standardized to receive the number per 1000m^2 of parcel area. It was decided to take the total canopy cover per 1000m^2 as a variable to account for the climate compensation of trees (*Canopy Cover of Trees*). The value *Ground Cover underneath the Trees* was first calculated as a weighted sum. Green ground cover accounts for a weight of 3, fallow ground cover or a tree pit for a weight of 2 and sealed ground for a weight of 1. These numbers were multiplied by the number of trees per category, summed up to one value for each parcel and standardized to result in a value per 1000m^2. After a first boxplot-analysis, it was observed that this value did not show any variety. It was then decided to add a weighted mean for the *Ground Cover underneath the Trees*. The values for the three different ground covers remained the same, the weighted sum was then divided by the total number of trees, which resulted in a value between 1 and 3. For the first analysis, both values were kept. The *Ground Cover underneath the Trees* influences the climate compensation of the trees above it. Trees growing on a sealed surface have a higher cooling potential than trees over a green ground cover as the ground is much hotter if it is sealed (Rahman et al., 2020). On the other hand, trees still have a cooling potential if they grow over green ground cover and most often, they grow better without a sealed surface.

To make a statement about the potential value of a tree species for biodiversity, the rating of Gloor et al. (2021) was used. They rated many urban tree species in respect to their value for several different organism groups such as butterflies, birds, or mosses. In this Thesis, the mean biodiversity value for all the tree species found on the parcel was calculated to state one biodiversity value of the tree community per parcel (*Biodiversity of Trees*). If a tree species was not represented in the rating of Gloor et al. (2021), it was dropped from the analysis. After a first look at the data, the ratio between coniferous and deciduous trees was dropped from the analysis, as its value was already represented in the variable *Biodiversity of Trees*.

Several landscape metrics were calculated, as described in Section 4.2.2, to measure the structural diversity of the parcels. The *SHDI* informs about the distribution of the different patches. The University of Massachusetts Amherst describes the *SHDI* as follows: "The *SHDI* increases as the number of different patch types increases and/or the proportional distribution of area among patch types becomes more equitable" (UMass, 2021). The *Edge Density Index* describes the structural diversity of the parcel as it is calculated by dividing the length of the edges of bushes and trees by the parcel area. To analyse the granularity of the parcels, the *Number of Patches* per $1000m^2$ was calculated. As a last structural variable, the *Mean Euclidean Distance* from each green patch to all others of the same parcel was calculated. If it is big, the green spaces are not distributed evenly across the parcel.

Additionally, the two design-variables *Fitting* and *Accessible* are part of the analysis. They do not directly contribute to the ecological quality of a green space, but they help to investigate whether the focus of the "especially good design" of *Area Developments* is on something else than ecological quality. If *Area Developments* are noticeably more easily accessible, then it might have been more important to provide green spaces for the broader public than to provide green spaces for ecology and biodiversity. Similarly, if these parcels fit much better in their city surrounding, then the quality of the overall urban space might have been the most important factor. They were both evaluated subjectively.

Table 3: Variables for final analysis.

Category	**Name**	**Unit**
Parcel Structure	Green Share	% of parcel
	Green Share Without Built Underground	% of green space
	Green Flat Roof Share	% of flat roof
	Number of Trees	number per $1000m^2$
	Edge Density Index	m per m^2
	Number of Patches	number per $1000m^2$
	Mean Euclidean Distance	-
	SHDI	-
Biodiversity	Bush Variable	m^2 (weighted)
	Undesirable Species	yes/no
	Natural Greening	m^2 per $1000m^2$
	Artificial Greening	m^2 per $1000m^2$
	Biodiversity of Trees	grade of 1 to 5
Climatic Effect	Number of Trees with Growing Potential	number per $1000m^2$
	Canopy Cover of Trees	m^2 per $1000m^2$
	Ground Cover underneath Trees (Sum)	m^2 (weighted)
	Ground Cover underneath Trees (Mean)	value of 1 to 3
Design	Fitting	yes(4) /rather yes (3) /rather no (2) /no (1)
	Accessible	yes(4) /rather yes (3) /rather no (2) /no (1)

As ecological quality is a complex concept, it is necessary to describe it from several different perspectives, which is why this analysis has as many dependent variables. The correlation analysis shows that most of the chosen variables do not correlate (Appendix D. There are two pairs of variables that are highly correlated. The *Number of Trees* and the *Number of Trees with Growing Potential* are the first pair. It was decided to keep the two variables for the statistical analysis to see if they differ in the different models. For the same reasons, the second pair of highly correlating variables were also kept: the *SHDI* and the *Mean Euclidean Distance*. They both consider the spatial distribution of the different patches with inverse meanings and have therefore a highly negative correlation. Overall, the correlation analysis confirms that it is important to look at all these different variables as they help to make statements about different aspects of ecological quality. The correlation analysis also includes the independent variable *Size of Parcel*. It was interesting to include it here to see if the standardization worked well, or if the *Size* correlates with any of the variables. It is visible that it does not and an influence of *Size* on the ecological quality as defined in this Thesis can be denied for a first time.

Finally, seven change variables were calculated. A change variable shows the difference between before and after the transformation for a certain variable. Not all the characteristics could be extracted from the aerial photograph from before the transformation, mostly due to the missing on-site analysis. Characteristics such as the *Bush Variable*, the *Biodiversity of Trees* or the *Undesirable Species* could not be detected solely from the aerial photograph. The structural variables that were calculated from the GIS-layers (*SHDI*, *Edge Density Index*, *Number of Patches*, *Mean Euclidean Distance*) were not computed for the aerial photograph from before the transformation due to the limited temporal scope of this Thesis. This led to the following seven change variables: Δ *Green Share*, Δ *Natural Greening*, Δ *Artificial Greening*, Δ *Number of Trees*, Δ *Ground Cover underneath the Trees (Mean)*, Δ *Canopy Cover of Trees*, and Δ *Number of Trees with Growing Potential*. These variables were analysed the same way as the other variables. The focus was mainly on the variables describing today's state. The change over time would be another possible focus of study.

In this Thesis, it was not evaluated for any variable, what value should be reached to deliver a "good" ecological quality. The Thesis only offers comparisons of higher and lower values that lead to certain conclusions about quality differences. In certain cases, the lower value might already be a "good" value, but the *Area Developments* should deliver an "especially good overall impression", so their values are expected to be higher in any case.

The following set of independent variables was defined to analyse the dependent variables and to respond to the second subquestion *Which other aspects could influence the ecological quality of parcels?*:

- **Presence of Policy instrument (*Area Development*)**: Primary Focus
- Type of Owner (private, building cooperative, city)
- Type of Use (residential use, mixed use, commercial use)
- Land Use before Transformation (unbuilt, built)
- Size of parcel (m^2)
- Age of buildings (years)

The *Presence of the Policy Instrument* is the variable which is primarily analysed in this Thesis, called *Policy Instrument* hereinafter. The other independent variables serve as covariates. The owners were identified through contacting the responsible administrations and then categorized into "private" (insurances, private people, real estate companies), "building cooperative" and "city". The different *Types of Use* were identified during the on-site analysis. "Mixed use" in this Thesis is defined as buildings with commercial use on the ground floor and/or additional office uses in at at least one of the upper storeys. If there were already buildings or, e.g., a parking lot, on the parcel before the transformation, it was labelled as "built" in the variable *Land Use before Transformation*. Parcels with gardens only or a green field development were labelled as "unbuilt" in this variable. This covariate describes the state of the parcel before the transformation in a much more simplified manner than the change variables. The age of the buildings was calculated from the building date from the data-set "Age of buildings". It was included to test if different trends concerning ecological quality were visible depending on the age of the constructions.

4.2.4 Statistical Analysis

To get an overview of the collected data, boxplots of each dependent variable were created, separated by the three groups defined in Table 2 (see all the boxplots in Appendix E). The boxplot for *Green Share* is displayed in Figure 3. Further, grouped boxplots divided by the independent variables *Type of Owner*, *Land Use before Transformation* and *Type of Use* were plotted to see possible inter-dependencies (Appendix F). This boxplot-analysis served as a first visual basis to get to know more about the data.

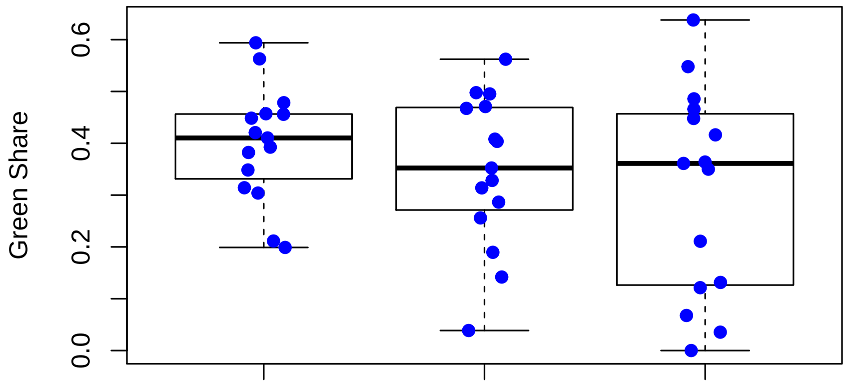


Figure 3: Boxplot of *Green Share*.

Subsequently, four different linear regressions were conducted for all dependent variables (Y) for the data of Group 1 and Group 2:

Model 1. Bivariate Model: Y ∼ *Policy Instrument*

Model 2. Multivariate Model (MLR): Y ∼ *Policy Instrument* + *Type of Owner* + *Type of Use* + *Land Use before Transformation*

Model 3. Size-Controlled Model (MLR): Y ∼ *Policy Instrument* + *Type of Owner* + *Type of Use* + *Land Use before Transformation* + ***Size***

Model 4. Full Model (MLR): Y ∼ *Policy Instrument* + *Type of Owner* + *Type of Use* + *Land Use before Transformation* + ***Size*** + ***Age***

The ordinal variables *Fitting* and *Accessible* were analysed with an ordinal logit regression, whereas the binomial variable *Undesirable Species* was analysed with a generalized linear model with the family "binomial". These variables were also analysed with four models with the same structure as the linear regression models listed above.

The Bivariate Model shows the simple connection between the respective variable and the *Policy Instrument*. The Multivariate Model adds more information about the parcels and controls for other factors. The Size-Controlled and the Full Model were added to ensure that *Size* and *Age* of the parcels do not influence the results.

All the variables were tested for normal distribution through a Histogram and a Shapiro-Wilk Test (Korstanje, 2021). The interpretation of the Histograms posed some challenges as the sample size with only 30 data points is small. Some variables showed deviations from a normal distribution so they were either log-transformed, or, if the deviations could be explained by outliers, the models were calculated again without those. If the differences of the two models were small, the outliers were kept for the final results, as they are not errors in the data collection.

With a Residual Analysis the regressions were additionally tested for the model assumptions. The Normal-QQ-Plot was part of this Residual-Analysis, it shows if the sample comes from a normal distribution. The Residual vs. Leverage Plot shows if there are data points whose removal would significantly influence the coefficients (Bommae, 2015). The Residuals vs. Fitted Plot tests the linearity of the sample (Pennstate, 2018). The plots were also accepted if they were not perfect as the sample size of 30 data points is small. The Histograms and Normal-QQ-Plots can be found in Appendix G. An Analysis of Variance (ANOVA) was conducted with the Multivariate, Size-Controlled and Full Model to see if the addition of the independent variables *Size* and *Age* could significantly improve the Multivariate Model. The ANOVA helps to find out if one model is able to explain more variance than another model (Phillips, 2018).

4.2.5 Expert Interviews

To complement the quantitative data from the data collection described above, four expert interviews were conducted. The qualitative data from these interviews helps to understand the functioning of the instrument of *Area Developments* and its utilisation in the city of Zurich. This allows the third subquestion of this Thesis to be answered: *How is the ecological quality of Area Developments evaluated in the building permission procedure?* The interviews were conducted following the method of Mieg and Näf (2005). They propose to interview experts following a semi-structured guideline which leaves room for a topic-specific conversation. The guiding questions for each interview can be found in Appendix H. Several questions were part of all four interviews to see the different views on the same topics. The other questions were chosen according to the specific field of knowledge of every interview partner. It was not the goal to gain comparable data as, e.g., in a population survey, but to acquire specific knowledge that only this specific expert can share. Experts were chosen according to their position in the planning system of the city of Zurich. It was most important to speak with someone from the Department for City Planning of the City of Zurich (AfS)[11], who is responsible for all the spatial development in the city of Zurich above ground. Two people from this department were interviewed: one from the "Unit for Architecture and Urban Space"[12] and someone from the "Unit for Area Developments and Planning"[13]. Additionally, someone from the Department for Green Spaces of the City of Zurich (GSZ)[14] was interviewed. GSZ is responsible for the maintenance of all the green spaces on city ground, and it has a consulting role for private developers.

The private sector should be included in the analysis as well; therefore, a planner from a local planning office was interviewed to get more knowledge about the planning of *Area Developments* and the collaboration between the city and private developers.

Three of the interviews were held online, one in person, and they all took 30 to 45 minutes. The protocol was taken directly and no transcripts were made afterwards. The summarized protocols can be found in Appendix I. All the interviewees agreed to the recording of the interview to ensure the possibility of relistening by the author. The interviewers are anonymized in this Thesis. The interviews are labelled with the unit or professions the experts work in.

[11]German: "Amt für Städtebau"
[12]German: "Fachbereich Architektur und Stadtraum"
[13]German: "Fachbereich für Arealentwicklungen und Planung"
[14]German: "Grün Stadt Zürich"

5 Results

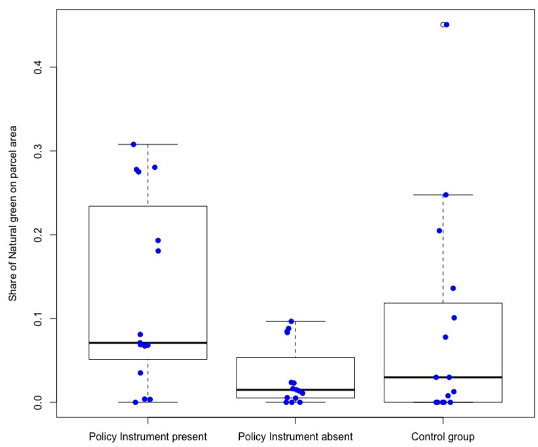
This section presents the results of the statistical analysis as well as the expert interviews. The main focus of this Thesis was on the quantitative data collection, as there were no previous studies that concentrated on the quality of the green spaces with respect to the specific instrument of *Area Developments*. The subsection Quantitative Results (Section 5.1) summarizes the outcomes of the statistical analysis of the collected data. The expert interviews were conducted to complement the quantitative data. They took place during and after the statistical analysis and the questions were informed by some initial results. Due to this, the Qualitative Results are displayed in a second subsection (Section 5.2).

5.1 Quantitative Results

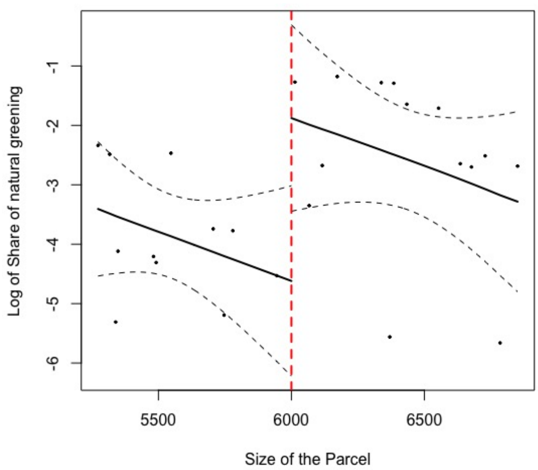
Overall, the statistical analysis indicated that the *Policy Instrument* does only partially influence the ecological quality of the green spaces. There are other controlling variables with a higher influence. Table 4 summarizes the most important facts across all the variables. The boxplots served as first visual aid, but apart from the differences in variance, no direct results were taken from them. The tables of all the regressions can be found in Appendix J. The Multivariate Model is the best model as it explains most of the variables best according to the ANOVAs. Table 5 displays the results of this model for all the dependent variables further used.

In the following sections, the results for the different dependent variables are listed. For each variable, the inputs of the boxplots as well as the significant variables of the regressions are mentioned. Additionally, the paragraphs contain information on the Residual Analysis, the ANOVA and the results of the Kruskall-Wallis Test. Where meaningful, the RDD-Plots are shown and described. Section 5.1.1 includes all the variables that were relevant for the discussion, listed in Table 6, whereas Section 5.1.2 explains why the remaining variables had to be dropped.

5.1.1 Results by Independent Variable



(a) Boxplot of *Natural Greening*.



(b) RDD-Plot of Log(*Natural Greening*) with 95% confidence intervals.

Figure 4: Plots of the analysis for the variable *Natural Greening*.

Natural Greening. The simple boxplots of the variable *Natural Greening* show a clear difference between the presence and the absence of the *Policy Instrument* (Fig. 4a). Additionally, the variance

Table 4: Summary of the significant results. This table shows which dependent variables were significantly influenced by the four independent variables, separated by the categories structural, biodiversity, climatic effect and design.

Independent Variables	**Dependent Structural Variables**	**Dependent Biodiversity Variables**	**Dependent Climatic Effect Variables**	**Dependent Design Variables**
Policy Instrument	Green Share (-10% without)	Natural Greening (-97% without)	0	Fitting (higher with) Accessible (higher with)
Type of Owner	Green Share Without Built Underground (+1% for building cooperative vs. private)	Natural Greening (city>private) Biodiversity of Trees (+0.5 grades for building cooperative vs. private)	0	Fitting (city>private) Accessible (building cooperative>private)
Type of Use	Green Share (-23% on mixed use) Bush Variable (-75% on mixed use) SHDI (mixed use<residential use) Edge Density Index (-50% on mixed use) Number of Patches (-8 patches on mixed use)	Artificial Greening (-25% on mixed use)	Number of Trees with Growing Potential (-2.6 trees on mixed use) Ground Cover Underneath Trees (Sum) (mixed use>residential use)	Accessible (mixed use>residential use)
Land Use Before Transformation	Number of Patches (-6 patches on unbuilt)	Natural Greening (built > unbuilt)	Number of Trees with Growing Potential (-1.6 trees on unbuilt)	Fitting (unbuilt>built)

Table 5: Regression-Table of the Multivariate Model for all dependent variables further used. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$. i.n.i.d. = if not indicated differently.

	Natural Greening (log)	**Green Share**	**Without Built Underground (log(x/(x-1)))**	**Bush Variable (log)**	**No. of Trees with Growing Potential**	**Canopy Cover of Trees**	**Ground Cover (Sum) (log)**	**Biodiversity of Trees**	**SHDI**	**Edge Density Index**	**Number of Patches**	**Fitting**	**Accessible**	**Artificial greening**
Intercept	-1.92 . (0.093)	0.6 *** (<1e-5)	0.14 (0.938)	4.79 *** (<1e-5)	5.65 ** (0.0011)	122.96 (0.11)	3.070 *** (<1e-5)	3.25 *** (<1e-5)	0.99 *** (<1e-5)	0.14 ** (0.0017)	13.50 * (0.017)	-	-	0.27 ** (0.0073)
Policy Instrument (absent)	-0.85 (0.15)	-0.098 . (0.062)	0.39 (0.68)	0.037 (0.92)	-0.89 (0.27)	1.89 (0.96)	-0.36 (0.25)	-0.097 (0.73)	-0.10 (0.23)	-0.0065 (0.76)	0.21 (0.94)	1.51 (0.15)	0.48 (0.56)	-0.014 (0.78)
Building Cooperative (Type of Owner 2)	-0.14 (0.82)	-0.025 (0.64)	1.69 (0.114)	-0.045 (0.91)	-0.28 (0.74)	-6.27 (0.88)	-0.097 (0.77)	0.46 (0.14)	0.024 (0.79)	0.033 (0.15)	4.40 (0.14)	-0.31 (0.78)	2.053 * (0.033)	0.023 (0.65)
City (Type of Owner 3)	1.28 (0.15)	-0.11 (0.14)	0.14 (0.92)	-0.24 (0.66)	0.036 (0.98)	-44.17 (0.43)	-0.29 (0.50)	0.35 (0.39)	-0.047 (0.70)	-0.018 (0.55)	2.63 (0.51)	-1.12 (0.51)	1.73 (0.16)	-0.085 (0.23)
Mixed Use (Type of Use 2)	0.82 (0.37)	-0.24 ** (0.0052)	-0.41 (0.76)	-1.38 * (0.030)	-2.60 * (0.044)	-94.00 (0.13)	-1.13 * (0.024)	0.20 (0.65)	-0.42 ** (0.0040)	-0.072 * (0.036)	-8.074 . (0.070)	0.029 (0.99)	3.67 * (0.017)	-0.25 ** (0.0026)
Unbuilt (Land Use Bef. Transf. 2)	-0.85 (0.2)	0.059 (0.27)	0.78 (0.41)	0.42 (0.30)	-1.61 . (0.060)	31.44 (0.43)	-0.43 (0.19)	0.060 (0.84)	-0.0073 (0.93)	0.014 (0.51)	-6.37 * (0.033)	19.10 *** (<1e-15)	1.36 (0.16)	0.038 (0.45)
No. of observations	26	30	26	30	30	30	30	30	30	30	30	30	30	30
R^2	0.35	0.39	0.18	0.27	0.25	0.16	0.24	0.14	0.36	0.34	0.38	-	-	0.42
Adjusted R^2	0.18	0.26	-0.026	0.12	0.093	-0.020	0.082	-0.044	0.23	0.20	0.25	-	-	0.30
Residual Std. Error (df=24 i.n.i.d.)	1.27 (df=20)	0.11	1.92 (df=20)	0.87	1.78	86.44	0.68	0.64	0.19	0.047	6.17	-	-	0.11
F-Statistic (df=5;24 i.n.i.d.)	2.11 (df=5;20)	3.01 *	0.87 (df=5;20)	1.75	1.59	0.89	1.52	0.76	2.73	2.43 .	2.92 *	-	-	3.44 *
Residual Deviance	-	-	-	-	-	-	-	-	-	-	-	44.084	68.55	-
AIC	-	-	-	-	-	-	-	-	-	-	-	60.084	84.55	-

Table 6: Independent variables in the Discussion.

Name	**Category**
Natural Greening	Biodiversity
Green Share	Biodiversity
Bush Variable	Biodiversity
Number of Trees with Growing Potential	Climatic Effect
Canopy Cover of Trees	Climatic Effect
Ground Cover Underneath Trees (Sum)	Climatic Effect
Biodiversity of Trees	Biodiversity
SHDI	Parcel Structure
Edge Density Index	Parcel Structure
Number of Patches	Parcel Structure
Fitting	Design
Accessible	Design
Artificial Greening	Biodiversity

of the data points is much higher in presence of the *Policy Instrument*. The regressions show significant results as well. To have a normal distribution the variable was log-transformed and the values of 0 were omitted. This transformation also improved the residuals of all models. Table 7 shows the results for the four models of the variable *Natural Greening*. The Bivariate Model, the Size-Controlled Model and the Full Model all show significant results for the *Policy Instrument*. The ANOVA shows that the Size-Controlled Model should be used for the variable *Natural Greening*, as it best describes the independent variable. Parcels without the *Policy Instrument* have on average 97% less *Natural Greening* than parcels with the *Policy Instrument*, which is a statistically significant effect. The RDD-Plot in Fig. 4b shows the discontinuity at the threshold of 6000m^2. There is a negligible overlap visible in the confidence intervals. Apart from the *Policy Instrument*, the independent variables *Type of Owner* and *Land Use before Transformation* have a significant impact on the share of *Natural Greening*. Parcels owned by the city have on average significantly more *Natural Greening* than parcels owned by privates. Parcels that were "unbuilt" before the transformation have now on average less *Natural Greening* than parcels that were "built" before the transformation. *Size* is another significant factor contributing to explaining the variance of *Natural Greening*. The coefficient is only very small, so this will not be taken into account in further discussions. The Kruskall-Wallis Test for the *Natural Greening*-variable validates the assumption of the RDD.

Green Share. The boxplots for the *Green Share* do not show any clear differences between the presence and the absence of the *Policy Instrument*. With the *Policy Instrument* present, the variance of the data points is smaller than with the *Policy Instrument* absent. The Multivariate Model shows a significant effect of the *Policy Instrument* for the *Green Share*. On average, the effect is approximately -10% for parcels without *Area Development*. This significant difference is displayed in the RDD-Plot in Fig. 5. The discontinuity at the threshold of 6000m^2 shows the difference between the parcels with and without *Area Development*. The overlap of the confidence intervals is explainable as the significant effect of the *Policy Instrument* is only visible once the Bivariate Model is expanded with all the covariates. The Multivariate Model is the best model according to the ANOVA. As the RDD-Plot only shows the simple relationship between the size and the *Green Share*, where the size is equivalent to the *Policy Instrument*, it does not show a significant discontinuity.

Type of Use influences the *Green Share* significantly as well. "Mixed use" parcels have on average approximately 23% less *Green Share* than "residential use" parcels. The Normal-QQ-Plot for *Green Share* is lightly tailed, indicating that compared to a completely normal distribution,

Table 7: Regression-Table of all the models for *Natural Greening* with a log-transformation. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model log(Natural greening)	**Multivariate Model log(Natural greening)**	**Size-Controlled Model log(Natural greening)**	**Full Model log(Natural greening)**
intercept	-1.43 . (0.083)	-1.92 . (0.093)	19.61 * (0.011)	19.55 * (0.018)
policy instrument (absent)	-1.16 * (0.033)	-0.85 (0.15)	-3.53 ** (0.0018)	-3.52 ** (0.0060)
building cooperative (Type of Owner 2)		-0.14 (0.82)	-0.57 (0.30)	-0.57 (0.31)
city (Type of Owner 3)		1.28 (0.15)	1.42 . (0.061)	1.42 . (0.068)
mixed use (Type of Use 2)		0.82 (0.37)	0.70 (0.36)	0.71 (0.40)
unbuilt (Land Use before Transformation 2)		-0.85 (0.20)	-1.40 * (0.022)	-1.39 * (0.049)
size			-0.0029 ** (0.0053)	-0.0029 * (0.010)
age				-0.0015 (0.98)
number of observations	26	26	26	26
R^2	0.18	0.35	0.57	0.57
adjusted R^2	0.14	0.18	0.43	0.40
Residual Std. Error	1.30 (df = 24)	1.27 (df=20)	1.055 (df = 19)	1.084 (df =18)
F statistic	5.15 * (df=1;24)	2.11 (df=5;20)	4.19 ** (df=6;19)	3.40 * (df=7;18)

there are slightly more data points at the extremes. Given the small sample of only 30 data points, it is still acceptable to assume this variable to be normally distributed. The Residual vs. Leverage Plot shows that there are no outliers that would affect the coefficients significantly if they were removed. The Kruskall-Wallis Test shows that the Control Group is not significantly different from the group without the *Policy Instrument* and the RDD-assumption is valid.

Green Share Without Built Underground. The boxplots for *Green Share Without Built Underground* show that the variance is bigger when the *Policy Instrument* is absent. For the linear regression, a normal distribution was achieved through a $\log(x/(1-x))$-transformation after removing the values of 0 and 1 to facilitate this transformation. *Green Share Without Built Underground* is not significantly affected by the *Policy Instrument* and the coefficients are very small in all four models. A significant effect can be seen for the independent variable *Type of Owner* in the Full Model. On average, parcels owned by a building cooperative have approximately 1% more *Green Share Without Built Underground* than parcels owned by private companies. However, the ANOVA reported that adding *Size* and *Age* does not significantly improve the Multivariate Model and the Full Model is therefore rather overfitting. Lastly, the Residual vs. Leverage Plot shows that there are two data points whose deletion would lead to a significant change of the coefficients. Since the two data points do not contain an error, they were kept. The Kruskall-Wallis Test shows that the Control Group is not significantly different from the group without the policy instrument and the RDD-assumption can be accepted.

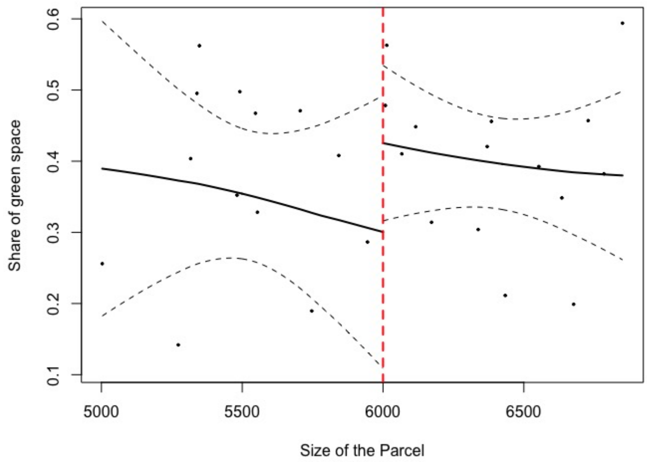


Figure 5: RDD-plot of *Green Share*.

Bush Variable. The boxplots for the *Bush Variable* do not show any interesting tendencies or differences. This variable was log-transformed for the linear regression. A significant effect of the independent variable *Type of Use* is visible in the regressions: On average, "mixed use" parcels have an approximately 75% smaller *Bush Variable* than "residential use" parcels. When looking at the definition of the *Bush Variable*, this means that they have on average either 75% less hedge row, 25% less species rich bush row, 37.5% less bush row that is poor in species or any combination of these. The ANOVA shows that the Size-Controlled Model improves the Multivariate Model, the significant effects are the same however. The Residual Analysis also confirmed that the Size-Controlled Model is the most ideal one, as the plots are closest to the ideal distribution for a linear regression. The Kruskall-Wallis Test for the *Bush Variable* does not deny the assumption of the RDD-Design.

Number of Trees with Growing Potential. The boxplots for the *Number of Trees with Growing Potential* does not show any interesting tendencies or differences. The variable is normally distributed and the Residual Analysis confirms the model assumptions. The *Number of Trees with Growing Potential* is significantly influenced by the *Type of Use* and the *Land Use before Transformation*. "Mixed use" parcels have on average 2.6 trees less than "residential use" parcels according to the Multivariate Model, which is not significantly improved by the addition of *Size* and *Age* according to the ANOVA. With a baseline of 5.6 trees (intercept), a change of 2.6 is quite high. If the parcel was "unbuilt" before the transformation, it has on average 1.6 trees less than if the parcel was "built". The effect of the *Policy Instrument* on the *Number of Trees with Growing Potential* is not significant and the coefficient is not remarkably high either. The Kruskall-Wallis Test for the *Number of Trees with Growing Potential* validates the RDD-assumption.

Canopy Cover of Trees. The boxplots of the *Canopy Cover of Trees* do not show any clear tendencies or differences. The regressions do not show any significant results in the four models neither. Although the ANOVA shows that the Size-Controlled Model and the Full Model do not significantly improve the Multivariate Model, the Residual Analysis shows much better plots for the Size-Controlled Model. The Kruskall-Wallis Test for the *Canopy Cover of Trees* do not deny the assumption of the RDD-Design.

Ground Cover Underneath the Trees (Sum). The boxplots for this variable do not show any interesting tendencies or differences. The log-transformed *Ground Cover Underneath the Trees (Sum)* is normally distributed and the Kruskall-Wallis Test allows for the RDD-assumption to be kept. This variable is highly influenced by the number of trees; it has the same outlier as the variable *Number of Trees*. It is nevertheless interesting that the independent variable *Type of Use* shows a significant effect on the ground cover: On average, "mixed use" parcels have a lower value than "residential use" parcels. This means that the ground cover underneath trees on "mixed use" parcels is on average rather sealed or a tree pit than a lawn or a hedge. The ANOVA shows that the Size-Controlled Model and the Full Model can not explain more than the Multivariate Model already does. The Residual Analysis shows one outlier that would significantly influence the coefficients if it was removed. As no error could be detected in this data point, it was kept in the analysis.

Biodiversity of Trees. The boxplots for the *Biodiversity of Trees* do not show any interesting tendencies or differences. This variable is not significantly influenced by the *Policy Instrument*. It is remarkable that the trees on parcels owned by a building cooperative have on average a biodiversity value that is 0.5 grades higher than trees on parcels owned by privates. This effect is significant in the Size-Controlled and the Full Model, while it is not significant in the Multivariate Model, which is the best one according to the Residual Analysis and the ANOVA. The distribution of the *Biodiversity of Trees* was highly influenced by two outliers with values smaller than two. Removing these two leads to a normal distribution. The model was calculated a second time without these outliers. Through this adjustment, the significant effects of the *Type of Owner* building cooperative was not present anymore. Nevertheless, the outliers are not errors and should therefore be kept in the model. The Kruskall-Wallis Test for the *Biodiversity of Trees* validates the RDD-assumption.

SHDI. The boxplots for the *SHDI* do not show any clear differences between the medians, but the variance of the parcels without the *Policy Instrument* seems to be bigger than the variance of the parcels with the *Policy Instrument*. Still, the regressions show that the *SHDI* is not significantly influenced by the *Policy Instrument*. According to the ANOVA and the Residual Analysis, the Multivariate Model is good enough and can not be improved by the addition of *Size* and *Age* as independent variables. "Mixed use" leads to a significant decrease of the *SHDI* in comparison to "residential use". This means that on "mixed use" parcels, there are either less patches or the existing patches are less equally distributed than on "residential use" parcels. The Kruskall-Wallis test for the *SHDI* validates the RDD-assumption.

Edge Density Index. The boxplots for the *Edge Density Index* do not display any interesting tendencies or differences. The regression shows that this variable is only significantly influenced by the *Type of Use*. The *Edge Density Index* of "mixed use" parcels is on average only 50% of the *Edge Density Index* of "residential use" parcels. As the index is calculated by measuring the edges of bushes and trees, this result suggests that "mixed use" parcels have less bushes and trees and therefore less structural diversity. This effect is visible in all three models that include *Type of Use* as an independent variable. The ANOVA shows that the addition of *Size* and *Age* does not significantly improve the Multivariate Model. The Normal-QQ-Plot for the *Edge Density Index* shows that the distribution is normal, and the Residual vs. Leverage Plot confirms that there are no outliers severely influencing the linear regression results. The Kruskall-Wallis Test for the *Edge Density Index* validates the RDD-assumption.

Number of Patches. The boxplots for the *Number of Patches* show a clear difference in variance between the presence and the absence of the *Policy Instrument*. In presence of the instrument, the variance is higher than in its absence. The variable *Number of Patches* is normally distributed, which was confirmed by the Residual Analysis. The *Policy Instrument* has no significant effect on the *Number of Patches*. *Type of Use* and *Land Use before Transformation* do significantly influence this variable, however. As the Multivariate Model is the best according to the ANOVA, the following values are taken from this model. While the intercept lies at 13.5 patches ("residential use" and "built" *Land Use before Transformation*), a "mixed use" parcel has on average 8 patches less. "Unbuilt" *Land Use before Transformation* leads to an average of 6 patches less. The *Number of Patches* is a measure for structural diversity and shows similar results as the *SHDI* and the *Edge Density Index*. The Kruskall-Wallis Test for the *Number of Patches* validates the RDD-assumption.

Fitting. The boxplots for the variable *Fitting* are not as informative as the ones of the variables described before as this variable is ordinal-scaled. Still, it is interesting to see that the variance is bigger on the parcels with the *Policy Instrument* than on the parcels without the *Policy Instrument*. The ordinal logit regression shows that on average, a parcel fits significantly better into the surroundings if the *Policy Instrument* is applied. Additionally, the *Type of Owner* "city" significantly influences the variable *Fitting*. On average, parcels owned by the city fit better into the surroundings than parcels owned by privates. Lastly, the *Land Use before Transformation* highly influences this variable. If the parcel was "unbuilt" before, it fits on average less in its surroundings now than if it was "built" before. The ANOVA shows that the Multivariate Model is precise enough, the influence of the *Type of Owner* "city" is therefore less relevant for further discussion, as it is only significant in the Size-Controlled and the Full Model. The Kruskall-Wallis Test confirmes the RDD-assumption for this variable.

Accessible. The boxplots for the variable *Accessible* do not show any clear tendencies. In the Size-Controlled and the Full Model of the ordinal logit regression, all the variables have a significant influence on the accessibility. The ANOVA shows that the Multivariate Model contains enough covariates to explain the variable. In the Multivariate Model, only the *Type of Owner* "building cooperative" and the *Type of Use* are significant. A parcel owned by a building cooperative is on average easier publicly accessible than a parcel owned by privates and a "mixed use" parcel is easier publicly accessible than a "residential use" parcel. The two bigger models suggest that the *Policy Instrument* has a significant effect on the variable *Accessible*. The coefficients are only small, but they show a tendency of a parcel being better accessible if the *Policy Instrument* is absent. The other two significant independent variables in the Size-Controlled and the Full Model are *Type of Owner* "city" and *Land Use before Transformation*. Similarly to the *Policy Instrument*, the coefficients are only small, but they suggest that a parcel owned by the city is on average rather publicly accessible than a parcel owned by privates and a parcel that was "unbuilt" before the transformation is on average rather publicly accessible than a parcel that was "built". The *Size* and the *Age* do not have a significant effect on this variable. The Kruskall-Wallis Test confirms the RDD-assumption.

Artificial Greening. Similarly to the variable *Natural Greening*, the boxplots for *Artificial Greening* show a tendency towards a difference between the presence and the absence of the *Policy Instrument* and a bigger variance in its absence. The Kruskall-Wallis Test of the variable shows that there are significant differences between the group without the instrument of *Area Developments* and the Control Group. Due to this, the assumption of the RDD-Design is not valid and the variable can not be used to study the effect of the *Area Development*. The models that include more than the *Policy Instrument*-variable can still show interesting results. “Mixed use” parcels have on average 25% less *Artificial Greening* than “residential use” parcels. This effect is significant in all three models that include this independent variable and it is not influenced by the non-valid assumption of the RDD-Design. The ANOVA shows that the Multivariate Model can not be significantly improved by adding *Size* and *Age* as independent variables. The Residual vs. Leverage Plot shows that there are no data points whose removal would significantly influence the coefficients.

5.1.2 Variables not Used in the Statistical Analysis

Number of Trees. The boxplots for the *Number of Trees* do not show any interesting tendencies or differences. The Residual Analysis shows that the variable *Number of Trees with Growing Potential* is better fitting for further analysis than *Number of Trees*. Additionally, the variable *Number of Trees* had to be log-transformed first to be normally distributed. It is highly influenced by one parcel that has a vast amount of trees. As this is no error, the outlier can not just be excluded. The variable *Number of Trees with Growing Potential* neutralises this outlier, as not all the trees are able to grow 50 years old. For all these reasons, the variable *Number of Trees* is not discussed further, even though it is significantly influenced by the *Policy Instrument*.

Mean Euclidean Distance. The boxplots for the *Mean Euclidean Distance* show a tendency for the value to be higher in absence of the *Policy Instrument*. For the regression, the *Mean Euclidean Distance* had to be log-transformed and one outlier at the top of the spectrum had to be removed to achieve a normal distribution. The linear regression shows that only the *Type of Use* has a significant influence on the *Mean Euclidean Distance*. On average, “mixed use” parcels have an approximately 2.3 times higher *Mean Euclidean Distance* than “residential use” parcels. This means that on any spot on the parcel, the distance to the next green structure is on average 2.3 times longer on “mixed use” parcels. The correlation analysis shows that the *Mean Euclidean Distance* and the *SHDI* are highly negatively correlated. The results of the regressions confirms this finding. It is therefore not advisable to discuss both these variables as they display similar insights about the structure of a parcel. As the Residual Analysis of the *SHDI* is better than the Residual Analysis of the *Mean Euclidean Distance*, the latter will not be discussed further.

Undesirable Species. The variable *Undesirable Species* is the only binomial variable in the analysis. Boxplots are not meaningful for a binomial variable, so none were compiled. The variable was analysed with a generalized linear model using the family “binomial”. There are no significant results and the presence of these *Undesirable Species* is not clearly explainable by any of the independent variables in this analysis. The ANOVA shows that the Size-Controlled Model improves the Multivariate Model and is therefore the model to look at. It is not possible to conduct a Kruskall-Wallis Test for a binomial variable, the medians of the two data groups are different however. This leads to a rejection of the RDD-assumption and this variable can not be used further.

Ground Cover Underneath the Trees (Mean). The variable of the *Ground Cover Underneath the Trees (Mean)* does not show a normal distribution. Additionally, the Kruskall-Wallis Test shows that the Control Group is significantly different from the group without the *Policy Instrument*. It was therefore decided to analyse the variable *Ground Cover Underneath the Trees (Sum)*.

Green Flat Roof Share. The variable of the *Green Flat Roof Share* will not be included in any further discussions due to three reasons:

1. The Kruskall-Wallis Test shows a significant result. The assumption of the RDD-Design is not valid. This was already suspected from the boxplots, where the median of the Control Group is clearly different from the median of the group without the *Policy Instrument*.
2. The flat roof is part of architectural structures and does not fit in line with the other analysed dependent variables.
3. The variable *Green Flat Roof Share* is not normally distributed and had to be transformed to conduct a proper linear regression.

5.1.3 Change Variables

For seven variables the difference between before and after the transformation was calculated using the data from the older aerial photographs to form change variables: *Green Share, Natural Greening, Artificial Greening, Number of Trees, Ground Cover Underneath the Trees (Mean), Canopy Cover of Trees, and Number of Trees with Growing Potential*. The variable Δ *Natural Greening* and the variable Δ *Ground Cover Underneath Trees (Mean)* had to be neglected, as they are not normally distributed. The only change variable significantly influenced by the *Policy Instrument* is Δ *Number of Trees*. The Multivariate Model shows that in absence of the *Policy Instrument*, the difference in number of trees between before and after the transformation is on average smaller than in presence of the *Policy Instrument*.

The independent variable *Land Use before Transformation* has a significant influence on the variables Δ *Green Share*, Δ *Artificial Greening*, and Δ *Canopy Cover of Trees*. The difference is smaller for "unbuilt" parcels before the transformation than for "built" parcels for the variables Δ *Green Share* and Δ *Artificial Greening*. This means that the change in *Green Share* and *Artificial Greening* caused by the transformation is smaller for parcels that were "unbuilt" before than for parcels that were "built". The Δ *Canopy Cover of Trees* on the other hand is bigger for parcels that were "unbuilt" before than for "built" parcels.

The variable Δ *Green Share* is additionally significantly influenced by the *Type of Owner* and the *Type of Use*. Parcels with a cooperative owner had on average a smaller change in *Green Share* than parcels owned by privates. "Mixed use" parcels had on average a bigger change in *Green Share* than parcels with "residential use".

5.2 Qualitative Results

To better understand the quantitative results of this Thesis, four expert interviews were conducted. This section summarizes the insights from all the interviews structured by the topics discussed: Importance of *Area Developments*, Evaluation of the Building Application, Monitoring, Reasons against using the Instrument of *Area Developments*, and the Development of the Instrument of *Area Developments*. Two of the interviewees work at the AfS in different roles and have different expertise. One expert works in the "Unit for Architecture and Urban Space" [15] and has in-depth knowledge about the Building Committee[16] which is responsible for the evaluation of building applications for *Area Developments*. The other expert of the AfS works in the "Unit for Area

[15] German: "Fachbereich Architektur und Stadtraum"
[16] German: "Baukollegium"

Developments and Planning"[17], which is responsible for the guidance of development projects that go beyond the BZO, such as "Design Plans"[18] or "Special Land Use Plans"[19]. A third interview was held with an expert from the GSZ working in the "Unit for Green Space Consulting"[20]. This unit is responsible for the evaluation of the green spaces in the building permission procedure and it advises developers on questions about green spaces. Lastly, a planner from a local spatial planning office was interviewed to include an opinion from outside of the city administration. A summary for each interview can be read in Appendix I.

Importance of *Area Developments*. All the experts emphasized the importance and advantages of *Area Developments*. As the developer wants to receive the density bonus, the city has a bigger lever to demand for high quality design (AfS, 2022a,b; GSZ, 2022). Due to their size, *Area Developments* have a higher responsibility concerning connectivity for the whole city and serve as exemplary projects for other developments (AfS, 2022b; GSZ, 2022; Stadt Zürich, 2021b). The instrument offers advantages for developers as well as for nature and green spaces: The possibility to build higher, apart from more densely, allows the footprint of the buildings to become smaller and increase the size of the surrounding green spaces (AfS, 2022b). The density bonus on the other hand is high: when someone wants to build in a zone that allows living on four storeys (W4) under "normal" law (BZO), 4 storeys with a density of 120% can be built; using the instrument of *Area Developments*, up to 7 storeys with a density of 160% can be built (Local Planning Office, 2022).

Evaluation of Building Applications. To ensure the "good overall impression" of *Area Developments*, the building applications need to be evaluated thoroughly. A developer decides if the judging panel of an architectural competition or the Building Committee evaluates the building project (Local Planning Office, 2022). The Building Committee consists of ten experts, out of which two have a background in landscape architecture or ecology (AfS, 2022a). The remaining eight experts focus on architecture or spatial planning. If the developer decides for the Building Committee to evaluate the project, the developer and the architect present the *Area Development* in a ten-minute presentation, leave the room and the committee discusses the project before presenting the decision to the project-team (Local Planning Office, 2022). The Building Committee evaluates a building application on several levels as, since 2012, there are five aspects that need to be looked at during the evaluation (AfS, 2022a),: embedding into the urban context, building volumes, physical development and topography, architectural expression, colors and materials. In the last ten years, climate adaptation and climate protection as well as social aspects have become more and more important and are now part of the evaluation as well. Concerning the climate, the laws and regulations are scarce. The following aspects were named as part of the evaluation:"Sectoral Plan for Heat Reduction", "Net-Zero-Strategy", higher tree canopy cover, less sealed area, share of green space, replacement planting of cut trees, and embedding in the surroundings (AfS, 2022a; GSZ, 2022; Stadt Zürich, 2020b). Apart from the missing legal basis, the expertise of the Building Committee does not lie on ecological quality (Local Planning Office, 2022).

Often, a competition procedure offers more time for the evaluation and the possibility to clearly define ecological criteria (Local Planning Office, 2022). These criteria are then evaluated by an expert who writes a report to inform the judging panel (Local Planning Office, 2022).

Overall, the focus of the evaluation of the "good overall impression" is primarily on urban space and living quality (GSZ, 2022; Local Planning Office, 2022). An *Area Development* needs to deliver

[17] German: "Fachbereich für Arealentwicklungen und Planung"
[18] German: "Gestaltungspläne"
[19] German: "Sondernutzungspläne"
[20] German: "Fachstelle Grünraumberatung"

a higher quality to its surroundings. This can be done through a publicly accessible green space, but just as well through valuable ground-floor uses (AfS, 2022a). In the last few years, ecological quality became more and more important in the whole city planning processes (AfS, 2022a,b; GSZ, 2022; Local Planning Office, 2022). This process started about 10 to 20 years ago, but it properly arrived in the planning documents and evaluation processes only in the last three to five years (GSZ, 2022; Local Planning Office, 2022). According to all the experts, this development is still happening and the importance of ecology and climate adaptation and mitigation is still rising.

Monitoring. The city has the option to ask for certain revisions and adaptions of the building application, as well as a plan of the surroundings (AfS, 2022a; GSZ, 2022). The only control of these additional requirements happens at the building inspection directly after the construction. The building inspector is often educated in architecture or spatial planning and mainly focuses on security aspects of the construction (AfS, 2022a; GSZ, 2022). The green spaces are rarely judged accordingly. This problem is recognized by GSZ and they aim to find solutions, but the resources are scarce (GSZ, 2022). There is no monitoring in place to enforce the implementation of the plans in the long term (AfS, 2022a; GSZ, 2022).

Reasons against using the Instrument of *Area Developments*. There are parcels that are big enough to use the instrument of *Area Developments* but do not do so. According to the two experts of the AfS, the costs and the higher requirements of an *Area Development* can discourage developers from building with this instrument (AfS, 2022a,b). Additionally, the possibilities to densify within the normal regulations of the BZO are already remarkable and it is not necessary to comply with the higher standards of an *Area Development* to gain more revenue through a transformation (AfS, 2022b). Other building regulations, e.g., the legally required distance from parcel borders, could be reasons to decide against the *Area Development* (Local Planning Office, 2022). The higher a building becomes the further away it needs to be from the parcel border. If a parcel has an inconvenient geometry, it might not be possible to use the whole density bonus. This could lead to a decision against the instrument, as it is not profitable anymore.

Development of the Instrument of *Area Developments*. The expert from AfS (2022b) explained that the threshold of $6000 m^2$ arose from an older version of the instrument, where there were different thresholds for different zones of the Zoning Plan. Today's threshold of $6000 m^2$ was defined when the instrument was simplified as it was the mean value of the older version.

There are different possibilities for the future development of the instrument. The critique of "island urbanism", stating that areas develop without incorporating the context of the development in the whole district or even the whole city, needs to be answered (AfS, 2022a; Hofer, 2016). This would be possible by introducing size-ranges instead of a hard threshold and by allowing building in phases, where every stage of the process needs to have an "especially good overall impression" (AfS, 2022a). One expert of the AfS (2022b) suggests to reduce the instruments that follow a bonus strategy and instead increase the quality requirements for the broad masses. This would mean including quality requirements concerning climate and density into the basic Zoning Plan.

6 Discussion

6.1 Thematic Discussion

Policy Instrument The results show that only two of the dependent variables measuring ecological quality are significantly influenced by the *Policy Instrument*. Additionally, the variables *Fitting* and *Accessible* showed significant effects, which points into the direction of the "good overall impression" being rather rated as a good urban space for people.

The first ecological variable that shows a significant result is *Green Share*. It is an important variable as it estimates the unsealed area of a parcel. The reduction of sealed surfaces is of value for species diversity as habitat spaces are increased (Bräuniger et al., 2010; Niemelä et al., 2011). The *Green Share* is one of the few variables that have a legal basis in the city of Zurich as there are benchmarks from the GSZ (Stadt Zürich, 2019a). The Building Committee takes this variable into account when evaluating building projects. Apart from the evaluation process, the result can be explained through the nature of *Area Developments* themselves. The density bonus allows developers to build denser and higher. The higher number of storeys naturally reduces the footprint of a building and therefore increases the *Green Share* of the parcel. The higher *Green Share* of *Area Developments* affirms the findings of Davies et al. (2009), who state that the contribution of domestic gardens to the urban green infrastructure is important and needs to be acknowledged. There are many domestic gardens that are of a big size and contribute substantially to the total urban green. GSZ is aware of this and the *Area Developments* are a good possibility for the city to intervene and implement their goals (GSZ, 2022).

Natural Greening is the second variable where the interventions showed significant results in this Thesis. There is no clear legal basis to increase the share of *Natural Greening*. Paragraph 71 Section 2c of the Cantonal Planning and Building Act (PBG) specifies that good surrounding spaces need to be part of the "good overall impression". This paragraph seems to lead the Building Committee to demand for natural rather than artificial greening. The difference in *Natural Greening* between *Area Developments* and parcels without the instrument is high. It is conceivable that landowners who comply with the instrument are aware of the ecological quality of urban green and therefore work with landscape architects that have experience in natural greening and attach importance to this aspect. The big difference in the amount of *Natural Greening* could be investigated in further studies.

Apart from the ecological variables, the two design variables *Fitting* and *Accessible* are influenced by the *Policy Instrument*. While the variable *Fitting* is significantly influenced, the variable *Accessible* is only significantly influenced in almost overfitting models. These variables show another aspect of *Area Developments*. The experts from the AfS confirmed that the "good overall impression" of these projects should be of value for the inhabitants and workers. An *Area Development* fits on average significantly better in its surroundings than a building project without the *Policy Instrument*. This suggests that the integration in the neighbourhood is important and has been part of development processes, which contradicts the critique of "island urbanism" (Appendix I). The accessibility of *Area Developments* is slightly higher than the accessibility of parcels without the instrument. If a parcel offers open and green space to the public, it offers quality urban space to a broader mass than only the tenants. With the city population growing, the pressure on public green spaces grows (Arnberger, 2012). Publicly accessibly private green spaces can help to reduce this pressure and increase the quality of life for city dwellers.

These results suggest that the hypothesis *"The green spaces of parcels with* Area Developments *have a higher quality than the green spaces of parcels without the instrument of* Area Developments*"*. can be partially confirmed. Only four out of 13 variables show a higher quality for the

Area Developments. However, due to the rather limited catalogue of ecological requirements for the building approval, this is more or less what could be expected, as will be discussed in the next paragraph.

Embedding the Results. The significant results need to be embedded in the framework of the assessed aspects of the instrument of *Area Developments* to evaluate for which variables results can be expected. PBG §71 mentions six aspects that need to be evaluated during the building permission procedure: (a) embedding in the surroundings; (b) building volumes and architectural expression; (c) placement, purpose, size, and design of surroundings; (d) living comfort and hygienic living conditions; (e) supply and disposal solutions; (f) kind and degree of equipment[21]. Aspect (a) is treated with the variable *Fitting*. For aspect (c), concerning the design of the surroundings, the structural variables of the analysis (*SHDI*, *Edge Density Index*, *Number of Patches*) were expected to show an effect, which they do not. The other aspects of the legal paragraph were not analysed in this Thesis.

The interviews raised the expectation for visible results in the climatic variables as the importance of climate mitigation and adaptation was mentioned regularly. The interview with the expert from the "Unit for Architecture and Urban Space" of the AfS emphasized that the *Green Share Without Built Underground* and the *Canopy Cover of Trees* are important factors in the building permission procedure. The results suggest that the *Policy Instrument* does not significantly influence these two variables. A possible explanation for these alleged shortcomings is the age of the developments analysed. They were developed since 1999, but the environmental discussion and the questions about climate adaptation and mitigation only arrived in urban planning in the last three to five years (AfS, 2022a; GSZ, 2022; Local Planning Office, 2022). Additionally, the city does not have the legal basis to demand for more high quality green spaces. The newest publication "Sectoral plan on City Trees" aims to increase the crown canopy of trees in the whole city (Stadt Zürich, 2022a). The fact that this plan was published in the year 2022 shows that up until now the instruments have not been sufficient.

Understanding the work of a committee helps to understand some of the results, and leads to some unresolved expectations. As the evaluation period of the committee for one project is not long, the evaluated criteria need to be easily recognisable. The variables that show a significant effect such as *Green Share* and *Natural Greening* are easily detectable. The *Number of Trees* can quickly be counted as well. Their distance from one another needs more analysis. This shows in the results, where *Number of Trees* is significantly influenced by the *Policy Instrument*, whereas *Number of Trees with Growing Potential* is not. This result reinforces the question whether the competence to evaluate green space quality is represented well enough in the Building Committee.

Type of Use. The results suggest that the dependent variable *Type of Use* is significantly influencing nine out of 13 independent variables. Generally, "residential use" has better values than "mixed use". In this Thesis "mixed use" was defined as parts of the buildings used for commercial or office purposes. Mostly, these other uses were placed on the ground floor, but some buildings had office spaces on multiple floors. The results with regard to this variable need to be put into perspective, as only 10 percent of the parcels analysed were categorised as "mixed use". The finding is nevertheless interesting as there is an ongoing discussion about the conflict between density and green spaces (Arnberger, 2012; Haaland and van Den Bosch, 2015). "Mixed

[21] German: "a. Beziehung zum Ortsbild sowie zur baulichen und landschaftlichen Umgebung, b. kubische Gliederung und architektonischer Ausdruck der Gebäude, c. Lage, Zweckbestimmung, Umfang und Gestaltung der Umgebungsanlagen, d. Wohnlichkeit und Wohnhygiene, e. Versorgungs- und Entsorgungslösung, f. Art und Grad der Ausrüstung"

use" is often promoted as a means to increase density and at the same time improve quality of the urban space (Netsch, 2021). This planning paradigm is challenged by the results of this Thesis suggesting that "mixed use" is in conflict with high quality green spaces. Up until now, the literature has focused on the influence of "mixed use" on urban space in general, rather than specifically studying its effects on green space quality. Further research about this particular effect is necessary to confirm the trend. The validation would lead to an increased need to counteract the conflict between densification an green spaces.

Analysing the "mixed use" parcels of this Thesis, the main constraints for the green spaces are the development areas such as parking lots, delivery areas, or parking garage entrances. The expert of GSZ mentioned the struggle between development areas and green spaces for "mixed use" parcels as well (GSZ, 2022). The biggest issue is therefore mobility: If there were less cars there would be more area for green space and biodiversity. The new publication "Participation in Mobility and Urban Spaces"[22] of the city of Zurich reports that the citizens wish a reduction of automobile traffic and an increase of the infrastructure for slow traffic (Stadt Zürich, 2022b). However, "mixed use" areas are in strong competition with, e.g., the easy accessible malls in the outskirts of cities and offer parking spaces to stay competitive. Considering the nine significantly influenced variables in more detail (Table 4), it is noticeable that all the structural variables are present except for the variable *Green Share Without Built Underground*. "Mixed use" parcels seem to offer less structural diversity, which would lead to less species diversity and, e.g., less nesting sites for insect pollinators (Cornelis and Hermy, 2004; Hall et al., 2017).

Other Independent Variables. The other independent variables shows less significant influence on the dependent variables. *Age* and *Size* could mostly be neglected from the analysis, as the ANOVAs showed that they did not significantly improve the model. Smith et al. (2005) showed that garden size played an important role for the composition of the garden. In this Thesis this effect can be reduced to close to zero through the design of the analysis and the standardisation of the variables.

The variable *Type of Owner* did have some significant influences (on the variables *Green Share Without Built Underground*, *Natural Greening*, *Biodiversity of Trees*, *Fitting*, *Accessible*). The parcels owned by the city tend to have better values in these variables. This could have been expected as it would be advisable for the city to implement their own goals. Other significant results can be explained by the nature of building cooperatives, where for example the parcels owned by cooperatives were easier accessible than privately owned parcels. Overall, the variable *Type of Owner* did not show surprising effects.

The variable *Land Use before Transformation* and the change variables can be discussed in combination. There are only few significant effects visible and it is difficult to explain them in detail. In this Thesis, the comparison to the state of the parcel before the transformation was not the primary research goal. The results did not show any surprising or remarkable effects that need to be analysed in more detail. The process of the transformation would be a research project in itself and should be analysed looking at other control variables including the neighbourhood, the state of development of the whole district, the density of the whole district, and similar factors.

Choice of Variables. The variables that have already been mentioned in the discussion can be designated as important as most of them show a certain effect. The *Bush Variable* has not been mentioned yet. It is a measure of the area and diversity of the bushes and hedges. The structural component of the variable is included in the *Edge Density Index*, that measures the

[22] German: "Mitwirkung Mobilität und Stadträume"

edges of bushes, hedges and trees. The diversity component of the variable is only marginally present as it is included in the weighted sum. The analysis showed that the *Bush Variable* is only influenced by the *Type of Use*. This influence is just as well displayed by the *Edge Density Index*. As there is not a lot of new information brought into the discussion by this variable and as it is difficult to interpret because it combines several aspects, it could be neglected in a future study.

The "Ground Cover Underneath the Trees" was a challenging characteristic. It is non-negotiable that this variable should be included in such an analysis as it influences the ecological value and the climate compensation potential of a tree. If the ground cover is green and natural, the tree can grow bigger and broader and offers more shade. If the ground cover is sealed, the temperature difference achieved by a tree is higher than if the ground cover is green (Rahman et al., 2020). The measurable effect is therefore higher, but only because the ground gets hotter if it is sealed. It is discussible if the weighted sum is the right way to include the ground cover underneath the trees, as it is difficult to interpret. Higher values are better because the trees can grow better, but when the values are lower, the temperature difference offered by the tree is higher. It would be interesting to find a measure that separates these two aspects of the ground cover underneath trees.

Another variable that has not been mentioned in the discussion yet is the *Biodiversity of Trees*. There were no significant differences visible, but it is nevertheless an important variable for the ecological quality and should not be neglected for future analyses. Tree species and their diversity have a high impact on climatic conditions in the city as well as on the species diversity of organisms depending on trees (Grote et al., 2016; Helletsgruber et al., 2020).

The three structural indices *SHDI*, *Number of Patches*, and *Edge Density Index* show similar results. It is important to have structural variables in an analysis such as the one in this Thesis to measure the structural diversity which leads to habitat diversity. It might be possible to neglect the *Number of Patches*, as it is similar to the SHDI but a bit less informative. This would have to be investigated in further detail.

The variable *Artificial Greening* helps to understand the green space of the whole parcel. If only the variable *Natural Greening* would exist, not all the important facts could be stated. The *Green Share* includes trees and bushes apart from the ground greening and to have only one of the two just mentioned variables would not show the whole picture of a parcel. As the RDD-assumption for the *Artificial Greening* had to be rejected, it was not possible to study the influence of the *Policy Instrument*. It would be interesting to analyse this relationship with a different study design.

Even with this big collection of 13 dependent variables, it is discussible if everything important has been pictured. The experts mentioned roof greening several times as it can be demanded by the city through the BZO. It had to be removed from the analysis of this Thesis because the RDD-assumption was not given. Additionally, the focus of this Thesis was on the surrounding green spaces. To have a complete picture about the ecological value of a parcel, it would be necessary to include this aspect along with information about energy consumption or grey energy.

Another factor that had to be neglected in this Thesis is the connectivity of the green spaces. Besides the size of the UGS, their connectivity plays an important role in determining their potential for species diversity (Bräuniger et al., 2010). When looking at the parcels on their own, the connectivity is not taken into account. The land uses around the parcel borders are part of the raw data, but they were neglected when determining the variables, as they were broadly defined and could not have been included in the models in this state. Special structures such as woodpiles or small water features would also be interesting to include in an analysis (Home et al., 2019). The characteristic *Water* was included in the data collection process but only very few features could be found and it was neglected before the statistical analysis. In a bigger study, it would be advisable to include these characteristics again.

Final statements. It is difficult to include ecological quality into urban environments. It has been shown that, e.g., species density for birds is negatively associated with urban land cover (Aronson et al., 2014). However, the results of this Thesis show that there are visible differences between the presence and the absence of *Area Developments* and between different *Types of Use*. It is important that the efforts of urban planning to increase the ecological quality are encouraged and promoted even further. This does not only matter for specific policy instruments such as the *Area Development*, but especially for the planning in the broad masses on the basis of the BZO. New legal baselines can help to enforce the intentions of the city administration to improve the urban space for nature, inhabitants and visitors.

6.2 Methodological Aspects

Aerial Photographs. The analysis could be even more thorough if an aerial photograph of every year was available. This would allow for a direct comparison of the parcels one year after the transformation. Since aerial photographs are not available for each year, the decision was taken to analyse the most recent photograph and control for the age of the buildings in the statistical analysis. For the analysis of the state before the transformation, the photograph closest to the time of construction was taken. Furthermore, the quality of the older aerial photographs is lower than the quality of the most recent pictures. This is naturally due to technical development and cannot be changed. It reduces the explanatory power of a comparison over time, as the grain size is not the same. This is one of the reasons why little emphasis was given to the temporal changes of the variables under investigation.

On-site Analysis. As stated in Wild (2013), assessing small-scale vegetation structures on aerial photographs is difficult. This made on-site inspections of every parcel necessary and most of the variable-values used in the statistical analysis were obtained from the on-site inspection. These values were supplemented with knowledge from the aerial photograph analysis. Having both aerial photography and on-site inspection allows for a more accurate depiction of the analysed parcels. The aerial photographs allow for a first understanding of the parcel and accelerate the digitalization process remarkably as already existing polygons can be reused and adjusted instead of drawn completely from scratch. For the on-site inspections, the main challenge was the accessibility. This led to the exclusion of parts of a parcel which could not be accessed. With more available time, the tenants could be contacted to access all the parts of all the parcels.

Expert Interviews. Quantitative data about the green spaces of the parcels alone can not be adequately interpreted without knowing how the instrument of *Area Developments* is applied by the authorities. Expert interviews help with the interpretation of the statistical analysis. Since they were conducted late in the process of the Thesis, they could only help to interpret the statistical data but not to inform the research question and the hypothesis.

Scalability. Due to the RDD-design, the applicability of the results of the Thesis is restricted to parcel sizes around the threshold of 6000m^2. It is feasible, however, that bigger *Area Developments* show higher ecological quality. Two interviewees mentioned that the instrument of *Area Developments* is valuable because it enforces quality standards on big parcels that can have a role model effect (AfS, 2022b; GSZ, 2022). This effect would have to be studied in further detail for bigger parcels than in this Thesis. Additionally, it is difficult to project the results of this Thesis on the whole city of Zurich since the sample size of 15 parcels per group is small. There was no possibility to increase the sample size as there were only 15 *Area Developments* with a parcel size of 6000m^2 to 7000m^2 as described in Section 4.2.2. Despite the sample size, certain results are statistically significant and show interesting trends that should not be neglected in future spatial planning in the city of Zurich.

Application to other Cities. The instrument of *Area Developments* is only applied in exactly this manner in the city of Zurich. Therefore, the findings of this Thesis can only be applied to the city of Zurich. Similar studies could be compiled in other Swiss cities to analyse the effects of their version of the *Area Developments*. For other countries, similar instruments could be identified and included in an analysis.

7 Conclusion

The main research question *What impact does the instrument of the* Area Developments *have on the ecological quality of the green spaces in the city of Zurich?* can be answered as follows: The evaluation of the "especially good overall impression" of *Area Developments* has a principal focus on the urban space, as shown by the significantly influenced variables *Fitting* and *Accessible*. It does, however, include certain aspects of ecological quality as well, which is displayed by the significantly higher values of *Green Share* as well as *Natural Greening* for parcels built with the regulations of *Area Developments*.

The results of this Thesis also suggests that "mixed use" can not guarantee high ecological quality for densification processes. "Mixed use" parcels displayed less *Green Share* and lower values for several other variables compared to "residential use" parcels.

The results of the Thesis show that the green infrastructure of the *Area Developments* can contribute to a higher recreational and ecological value of the whole city as mentioned by Bräuniger et al. (2010). The biodiversity itself, which is measured by, e.g., habitat diversity, could still be improved to reach the full potential of specific urban niches (e.g., Nielsen et al., 2014; Sushinsky et al., 2013). The variables of the category "climatic effect" were not significantly influenced by the instrument of *Area Developments*, which means that up until now, they could not contribute to the reduction of the UHI-effect as described in Section 2.

The recommendations that emerge from these results are explained in the following section.

7.1 Policy Recommendations

The instrument of *Area Developments* does not reach its full potential in aiding to accomplish the environmental goals of the city of Zurich yet. If the quality criteria for the surrounding spaces are more clearly defined and more stringently included in the evaluation process, *Area Developments* can contribute to more than just high quality densification. To facilitate this change in the specific instrument of the *Area Developments*, this Thesis recommends to rethink four aspects of the complete urban planning process:

- There is a need to clearly define what ecological quality means to the city of Zurich,
- the legal basis to demand higher quality must be strengthened,
- the competences to evaluate ecological criteria should be increased in the responsible panels, and
- the collaboration with several other important fields and disciplines, e.g., mobility, traffic, or ecology, should be strengthened.

It is easy to ask for high quality green spaces, but it is difficult to define what "high quality" means. First, the question arises if high quality needs to be for people or for nature. The existing strategic documents of the city of Zurich suggest that people should be prioritised, but nature gains in importance. To further enable the implementation of this "high ecological quality", additional measurable and monitorable criteria for high ecological quality need to be defined. Up until now, there are only few such measures present: The GSZ has goals for the share of green space on the whole city area; there is a benchmark for the amount green space per person, and there are specific requirements for roof greening, so it can reach its ecological potential (AfS, 2022a; GSZ, 2022; Stadt Zürich, 2019a; Sutter, 2020). New measures should be introduced on the city level as well as on the parcel level. In this Thesis, 13 variables were chosen to describe the ecological quality of parcels. In the future, it will be necessary to have a collection of variables and indices to measure the quality of green spaces. In this collection, the four categories of this Thesis should be represented: parcel structure, biodiversity, climatic effect and design. These categories overlap and some variables can be categorized into two different groups. To achieve high quality for nature and people, they will all be important and should be taken into account separately as well as combined.

Once such a collection of criteria is set, it has to be translated into legal building requirements. During the data collection for this Thesis it became clear that oftentimes the knowledge and the awareness about green spaces and their quality is present, but the legal basis to ask for further measures does not exist. Such a legal basis for more ecology and more climate adaptation and mitigation needs to be created. On the basis of this law, the Zoning Plan should be adapted and additional regulations should be introduced to secure high quality green spaces not only for *Area Developments*, but for all the building projects in the city of Zurich.

Even with such new regulations in place, it will be vital to hire people with the right background and knowledge to implement them. Urban planning will become more diverse and should include environmental specialists and ecologists accompanying a project from start to finish, including the building process and the monitoring after the construction. When the construction is finished, the ecology only just starts to develop. The custom of accepting the surroundings together with the buildings at the building inspection should be questioned, as several features of the gardens and green spaces are not yet visible. It should be done at a later point in time by a specialist for UGS rather than a specialist for architecture, city planning, and safety regulations.

The collaboration with other parts of the administration will stay important. This collaboration already happens but it should be increased to analyse if certain standards could be altered to emphasize green and ecological infrastructure. Combined with the integration of new disciplines, the field of urban planning must become even more diverse than it already is. Specifically, due to the conflict between "mixed use" and green spaces, a collaboration with people responsible for mobility is should be aimed for.

The suggested policy recommendations all concentrate on the city, but up until now the city only has limited possibilities to influence the building activity of developers. There is a conflict between the economic interests of developers and the ecology. The *Area Development* focuses on the economic interest and gives an economic incentive to design high quality buildings. Maybe this conflict could be tackled from another angle. To inform and educate the developers about the natural advantages of high quality surroundings could make a difference: high quality green spaces increase the willingness of people to live there. The interviews showed that there are developers that are aware of these advantages and they propose high quality surroundings already by themselves. It is necessary to include climate mitigation, climate adaptation and ecology in the education of future architects, city planners, and landscape architects to increase the awareness about the ecological and economic advantages. The responsibility for high quality living conditions in the city of Zurich lies not only with the city administration, but also with developers, landowners and residents. The policy recommendations help the city administration to extend its reach, but it will be necessary for developers to increase their willingness to produce ecologically valuable developments to achieve a city that is adapted to future environmental conditions.

7.2 Outlook

Ecological quality only became an important topic in urban planning in the last three to five years. This Thesis could not yet picture this as planning processes take time and many of the analysed parcels were developed before the trend started. A repetition of this analysis in ten years could be valuable to see the achievements of newer strategies such as the "Sectoral Plan on City Trees" or the newest Communal Structure Plan (Stadt Zürich, 2021a, 2022a).

Such a future study could include more parcels to represent a bigger range of possible developments and therefore increase the explanatory power. Several interesting *Area Developments*, that are bigger than the bandwidth of this Thesis, were mentioned in the interviews (AfS, 2022a; GSZ, 2022). Further, analysing subcategories such as parcels from the same zone or the same *Type of Owner* could improve the interpretation of the results, as more detailed information can be gathered. Adding more interviews, e.g., with developers and landowners, could additionally increase the understanding of the needs and interests of these groups which leads to a better knowledge of the whole developing process and an even more informed discussion of quantitative results.

The ecological quality of different *Types of Use* should be studied in detail in the future. People living in "mixed use" buildings should profit from high ecological surroundings just as much as people living in "residential use" buildings. High quality densification should not contradict high quality ecological surroundings. This conflict, depicted in this Thesis, needs to be tackled by research and planning in the future.

This Thesis represents one part of a Policy Impact Assessment of the policy instrument *Area Development*. Besides the ecological quality, the social, as well as the architectural and urban space quality are important. Analyses with a similar design, but studying these other aspects of development projects would complement this Thesis. The combination of these analyses could deliver a complete Policy Impact Assessment for the instrument of *Area Developments*.

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Appendices

A On-site Protocol

Table A.1: Protocol used for the on-site inspections.

Objectnr.	filled out
Parcel Nr.	filled out
Address:	filled out
Group:	filled out
Year built:	filled out
Zoning:	filled out

		on site (DATE AND TIME)	comments
Raster on site			
general comments:			
Hedgerow			
single bush (number)			
hedgerow			
bushrow			
number of bush species			
bush row rich in species (yes, no)			
undesirable species (yes, no)			
	Prunus laurocerasus		
	Thuja sp.		
	Cotoneaster sp.		
	Buddleja davidii		
Greening			
lawn, rather poor in species (m2)			
meadow, rather rich in species (m2)			
uncultivated/neglected/bare ground (m2)			
fallow vegetation (m2)			
agriculture			
garden			
Walls			
Wall (m2)			
nature friendly (yes/no)			
water			
number of fountains, ponds and streams			
close to nature small water (m2)			
Trees			
Number of trees total			
No. Of trees with small volume (until 5m d)			
No. Of trees with medium volume (5-10m d)			
No. Of trees with big volume (more than 10m d)			
No. Of trees with fallow understory/tree pit			
No. Of trees with ornamental hedge, lawn or meadow			
No. Of trees in tree raster without tree pit (sealed)			
No. Of trees with potential to grow older than 50 years (only distance, without mortality)			
No. Of trees ¡3m			
No. Of trees ¿3m			
Tree species			
No. Of coniferous trees			
No. Of decidious trees			
Housing type			
Density			
Number of storeys			
group of society			
Social benefit			
publicly accessible			

B List of Green Space Characteristics

Sources for the list of green space characteristics: Aronson et al. (2014); Bräuniger et al. (2010); Cornelis and Hermy (2004); Davies et al. (2009); Douglas and Philip (2014); Grote et al. (2016); Helletsgruber et al. (2020); Home et al. (2019); Loram et al. (2008); McDonnell and MacGregor-Fors (2016); Niemelä et al. (2011); Rahman et al. (2020); Sattler et al. (2010); Smith et al. (2005); Vogt et al. (2017); Wild (2013)

Table A.2: List of green space characteristics. The Crosses on the right side show which characteristic was collected in which step of the data collection. "Before" stands for the aerial photograph analysis of before the construction, "After" stands for the analysis of the aerial photograph of 2020, and "On-site" stands for the on-site inspection.

Factor		Before	After	On-site
Objectnr.		X	X	X
Parcel Nr.		X	X	X
Address:		X	X	X
Group:		X	X	X
Year built:		X	X	X
Zoning:		X	X	X
general comments:		X	X	X
Size of Parcel (m2)		X	X	
Size of green space (m2)		X	X	
fragmentation (yes, no)		X	X	
Basement				
sealed area (m2)		X		
area with basement (m2)			X	
green area with basement (m2)			X	
green area without basement (m)			X	
Hedgerow				
bush (number)		X	X	X
hedgerow		X	X	X
bush row		X	X	X
number of bush species				X
bush row rich in species (yes, no)				X
undesirable species (yes, no)				X
	Prunus laurocerasus			X
	Thuja sp.			X
	Cotoneaster sp.			X
	Buddleja davidii			X
Greening				
lawn, rather poor in species (m2)		X	X	X
meadow, rather rich in species (m2)		X	X	X
uncultivated/neglected/bare ground (m2)		X	X	X
fallow vegetation (m2)		X	X	X
agrictultural field (m2)		X	X	X
gardens		X	X	X
Walls				
Wall (m2)		X	X	X
nature friendly (yes/no) (ex. dry stone wall)		X	X	X
Flat roofs				
flat roof (m2)		X	X	
thereof flat roof greened/brown roof (m2)		X	X	

Table A.3: List of green space characteristics. Continued.

Factor	Before	After	On-site
Water			
number of fountains, ponds and streams	X	X	X
close to nature small water (m2)	X	X	X
Trees			
Number of trees total	X	X	X
No. Of trees with small volume (until 5m d)	X	X	X
No. Of trees with medium volume (5-10m d)	X	X	X
No. Of trees with big volume (more than 10m d)	X	X	X
No. Of trees with fallow understory/tree pit	X	X	X
No. Of trees in tree ratser with ornamental hedge, lawn or meadow	X	X	X
No. Of trees in tree raster without tree pit (sealed)	X	X	X
No. Of trees with potential to grow older than 50 years (only distance, without mortality)	X	X	X
No. Of trees <3m		X	X
No. Of trees >3m		X	X
tree species			x
No. Of coniferous trees	X	X	X
No. Of decidious trees	X	X	X
No. Of different structures on parcel	X	X	x
Distance to urban edge	X	X	
Land cover adjacent to the parcel			
green (garden, agriculture, parks, etc.) in % of the parcel border	X	X	
buildings in m	X	X	
streets in m	X	X	
Housing type	X	X	x
Overall assessment			
for parcel	X	X	
for 5m buffer around parcel	X	X	
Fitting in district (yes, no)	X	X	
Density			
basal area of building	X	X	
Number of storeys	X	X	x
living area	X	X	x
living area per parcel area	X	X	x
group of society	X	X	x
Social value			
Publicly accessible			x

C PCA of all six Greening Variables

The PCA of the greening variables was conducted with the following variables: lawn, meadow, bare ground, fallow vegetation and garden. As the variable "agriculture" was always 0 in the data of the analysis of today's situation, it was neglected from the PCA. Table A.4 displays the values for the Principal Component (PC) for each of the variable. Figure A.1 visualises PC1 and PC2 in a biplot. It shows nicely that garden, lawn and bare ground have a positive PC1, whereas fallow vegetation and meadow show in the other direction. Due to this, the combination to the two variables *Natural Greening* and *Artificial Greening* was conducted. The Scree-Plot in Fig. A.2 shows that PC1 is only able to explain a little bit more than 25% of the variance.

Table A.4: Principal Components for the PCA of the Greening Variables.

	PC1	PC2	PC3	PC4	PC5
lawn	0.6384	−0.1249	−0.2881	−0.3098	−0.6308
meadow	−0.4718	−0.4902	0.4169	0.0591	−0.5998
bare ground	0.2079	−0.6948	−0.3343	0.5576	0.2269
fallow vegetation	−0.3771	0.3923	−0.5991	0.4321	−0.3979
garden	0.4295	0.3279	0.5220	0.6348	−0.1805

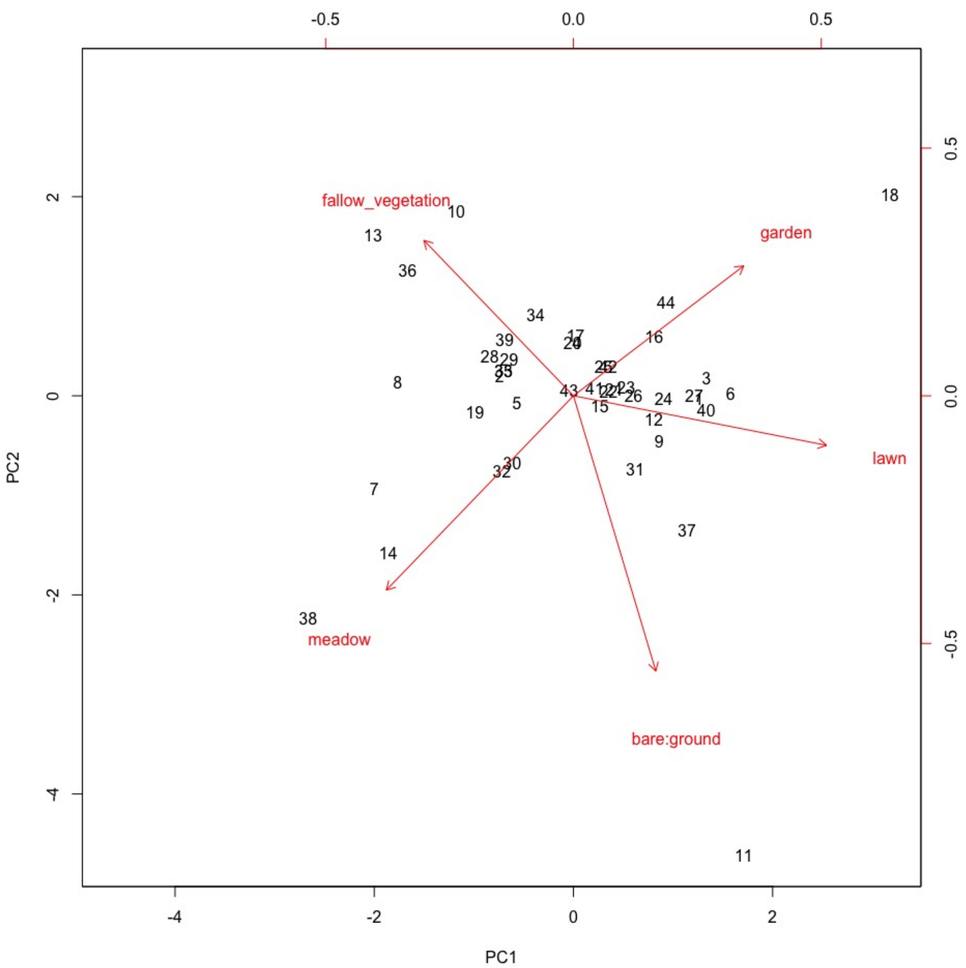

Figure A.1: Biplot of PC1 and PC2 of the PCA of the Greening Variables.

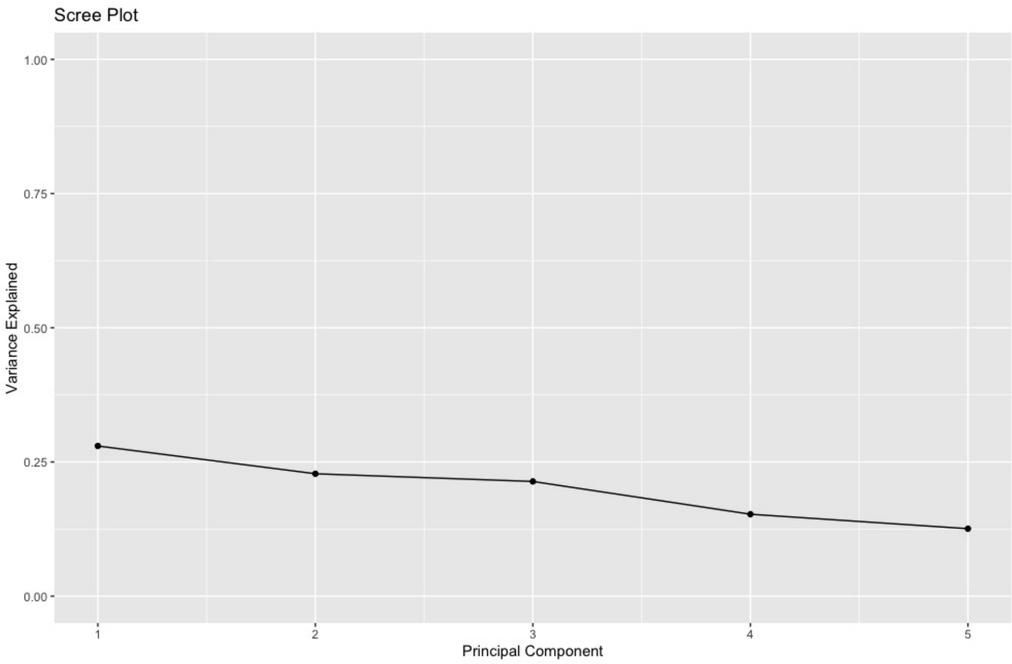

Figure A.2: Scree-Plot of the PCA of the Greening Variables.

D Correlation Analysis of all Dependent Variables

Figure A.3 shows the correlation analysis of all the dependent variables that are interval-scaled. The variables carry their working names in Fig. A.3. The bigger the circle the bigger the correlation.

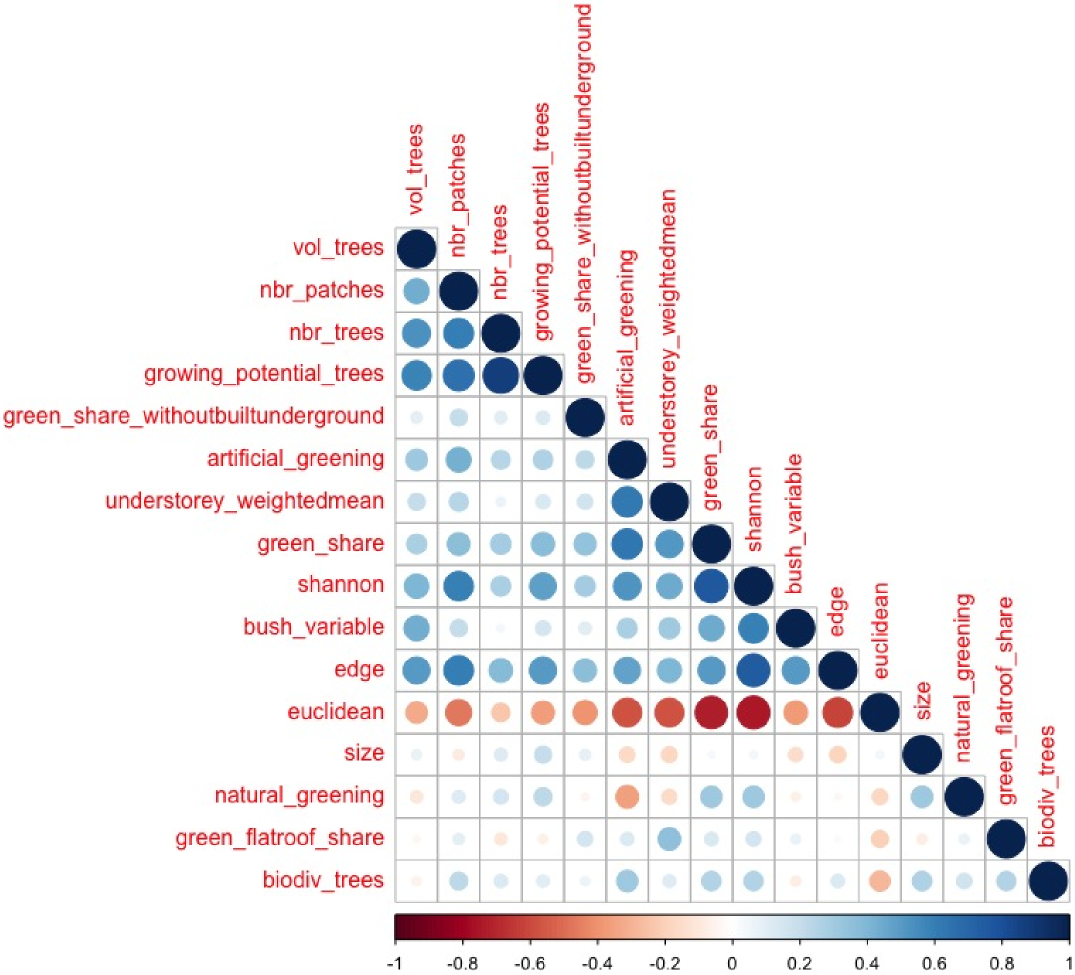

Figure A.3: Correlation analysis of all the numeric variables.

E Boxplots for each Dependent Variable

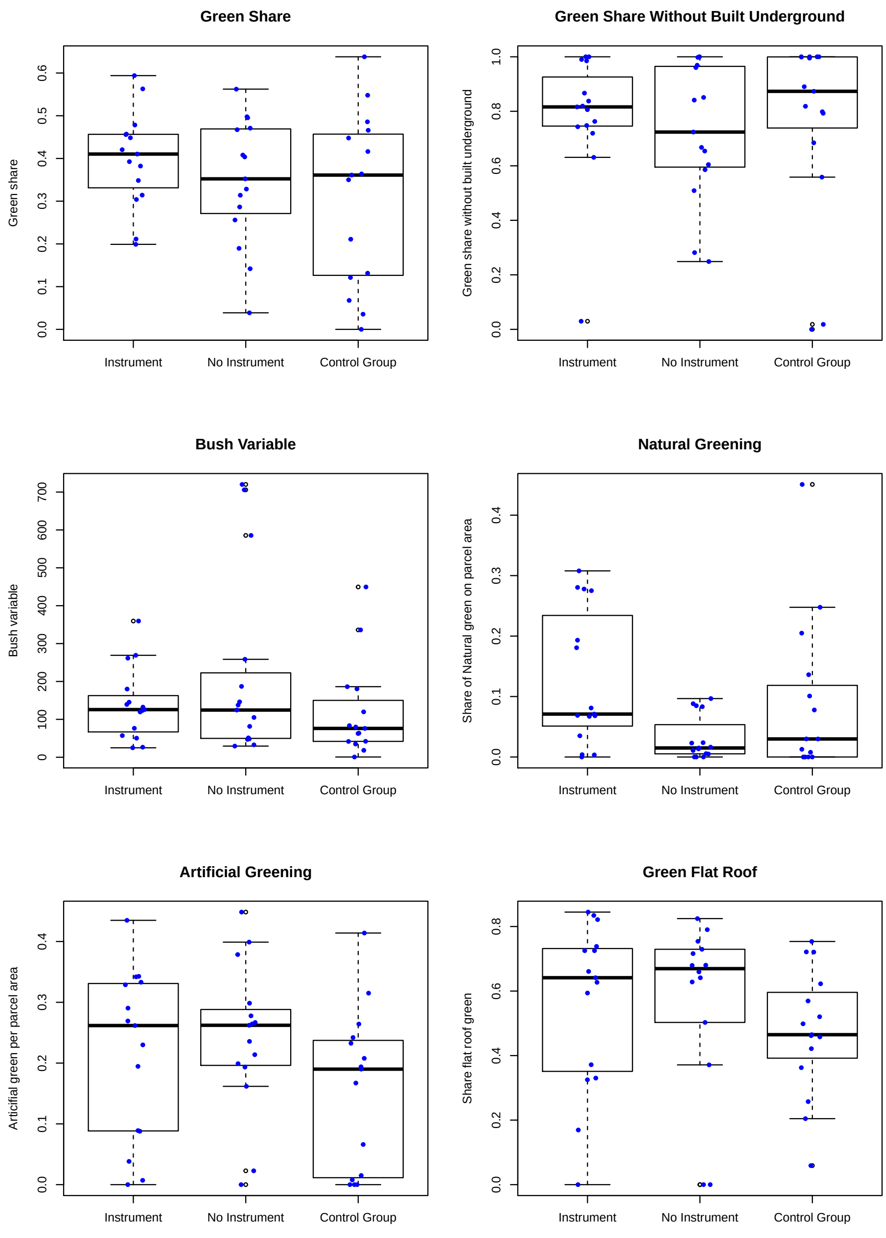

Figure A.4: Boxplots of variables 1 to 6.

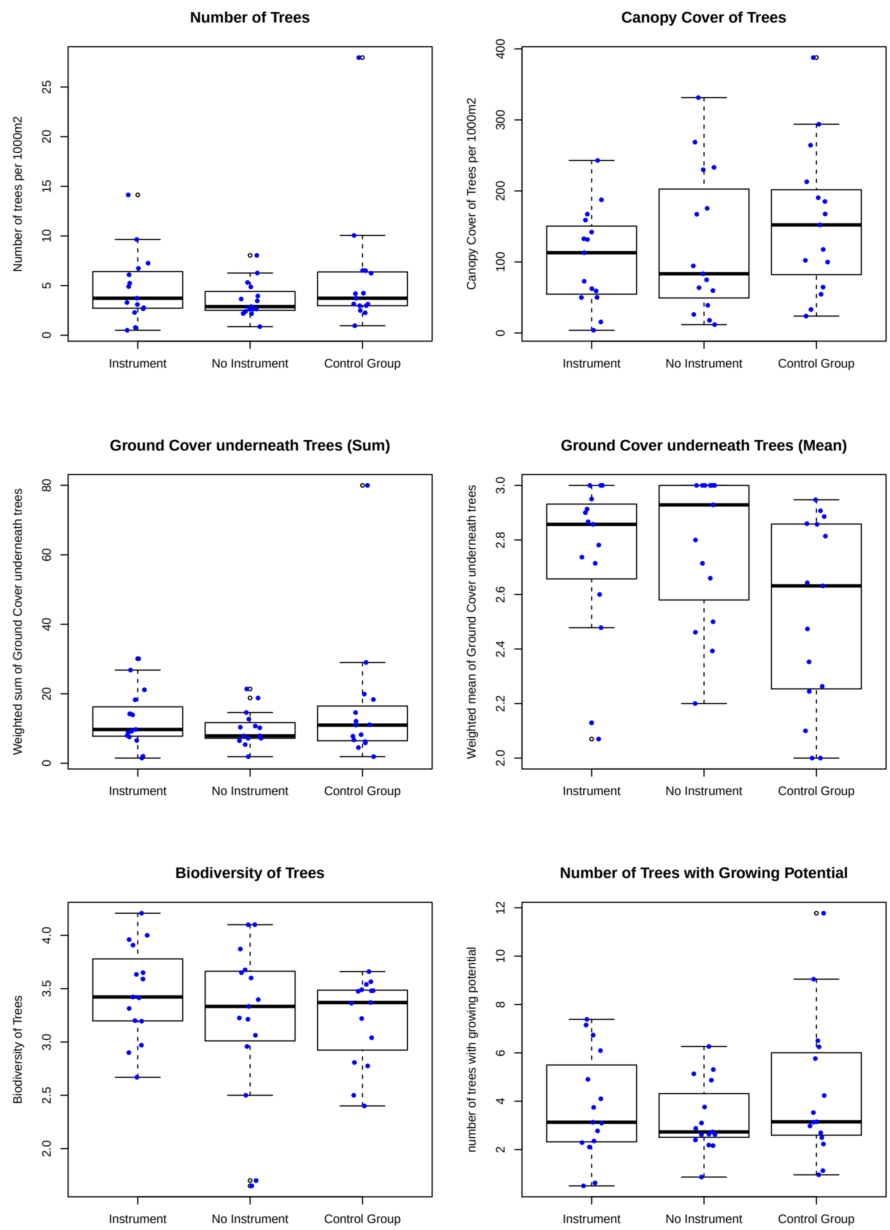

Figure A.5: Boxplots of variables 7 to 12.

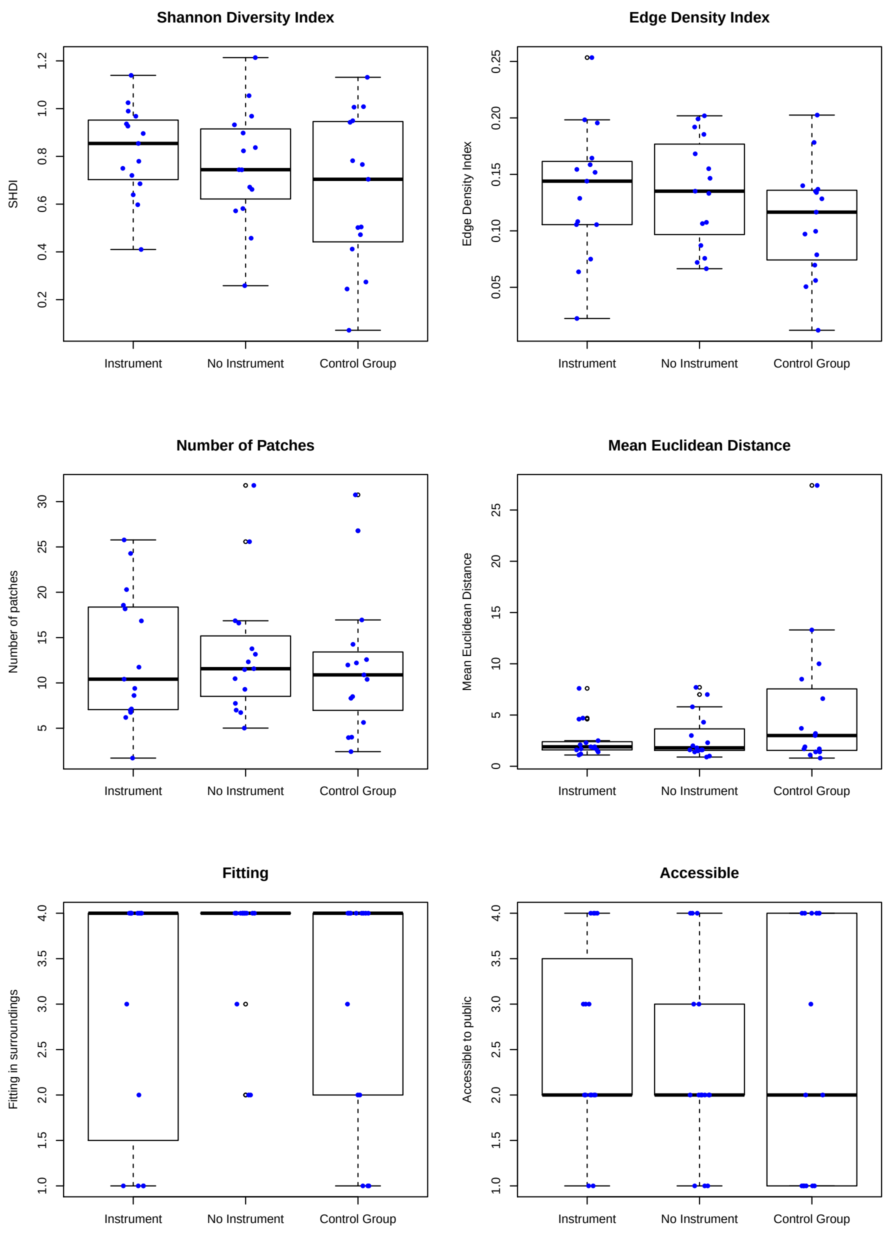

Figure A.6: Boxplots of variables 13 to 18.

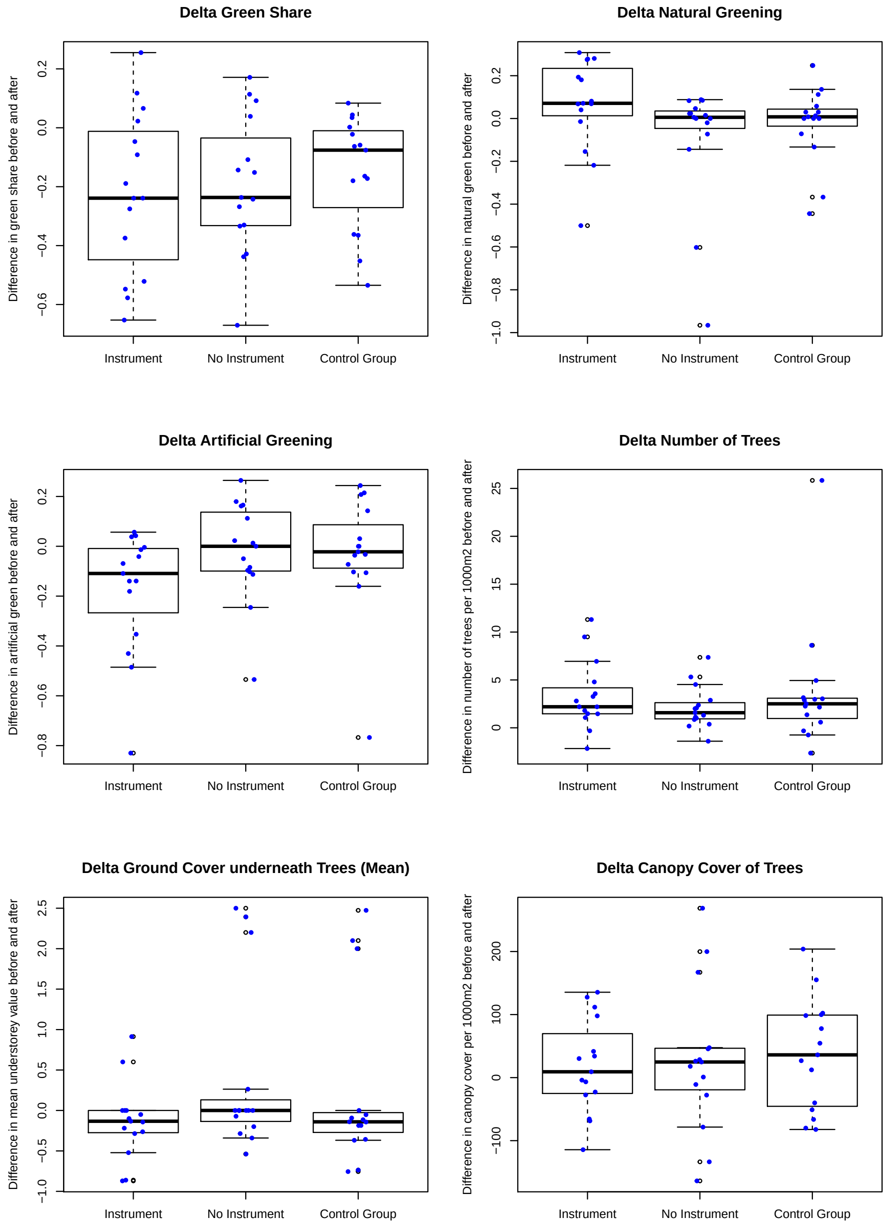

Figure A.7: Boxplots of variables 19 to 24.

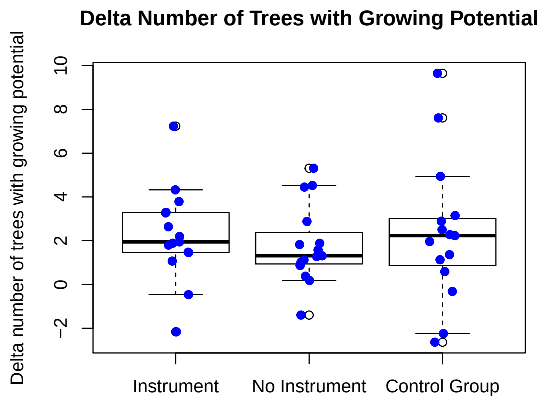

Figure A.8: Boxplot of variable 25.

F Grouped Boxplots for each Dependent Variable

There were no grouped boxplots compiled for the ordinal-scaled variables *Fitting* and *Accessible*, as well as for the binomial variable *Undesirable Species*. For all the displayed grouped boxplots, the following code is applied:

Group 1 = Area Developments
Group 2 = No Area Developments
Group 3 = Control Group

Type of Owner 1 = Private
Type of Owner 2 = Cooperative
Type of Owner 3 = City

Type of Use 1 = residential use
Type of Use 2 = mixed use
Type of Use 3 = commercial use

Before transformation bult = built use before the transformation
Before transformation unbl = unbuilt use before the transformation

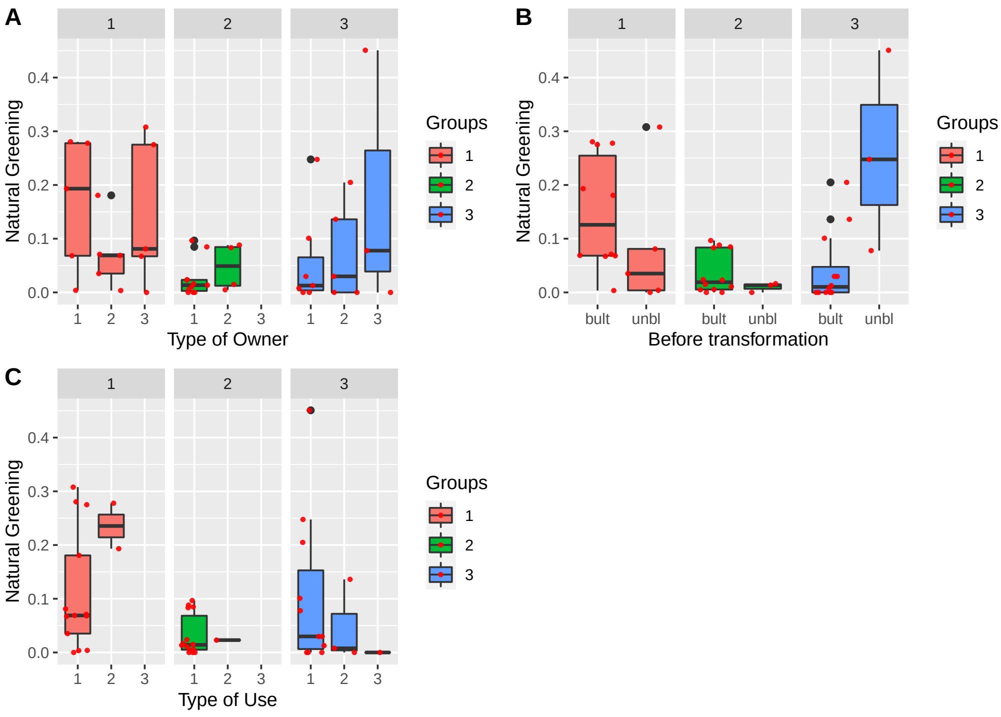

Figure A.9: Grouped Boxplots of *Natural Greening*.

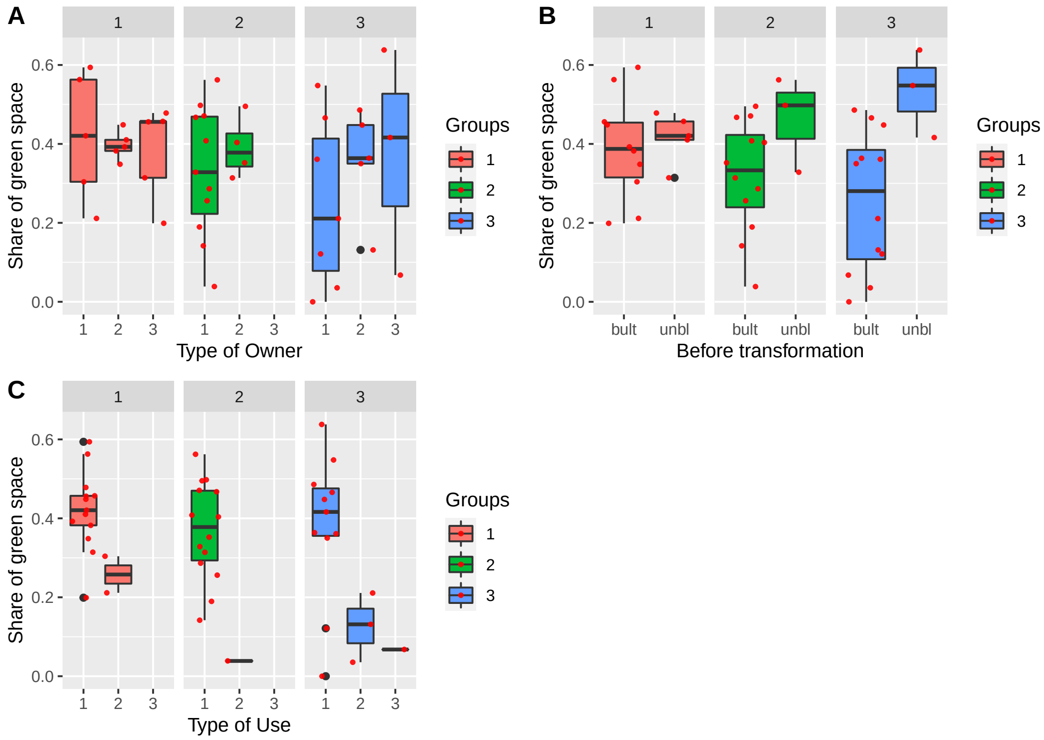

Figure A.10: Grouped Boxplots of *Green Share*.

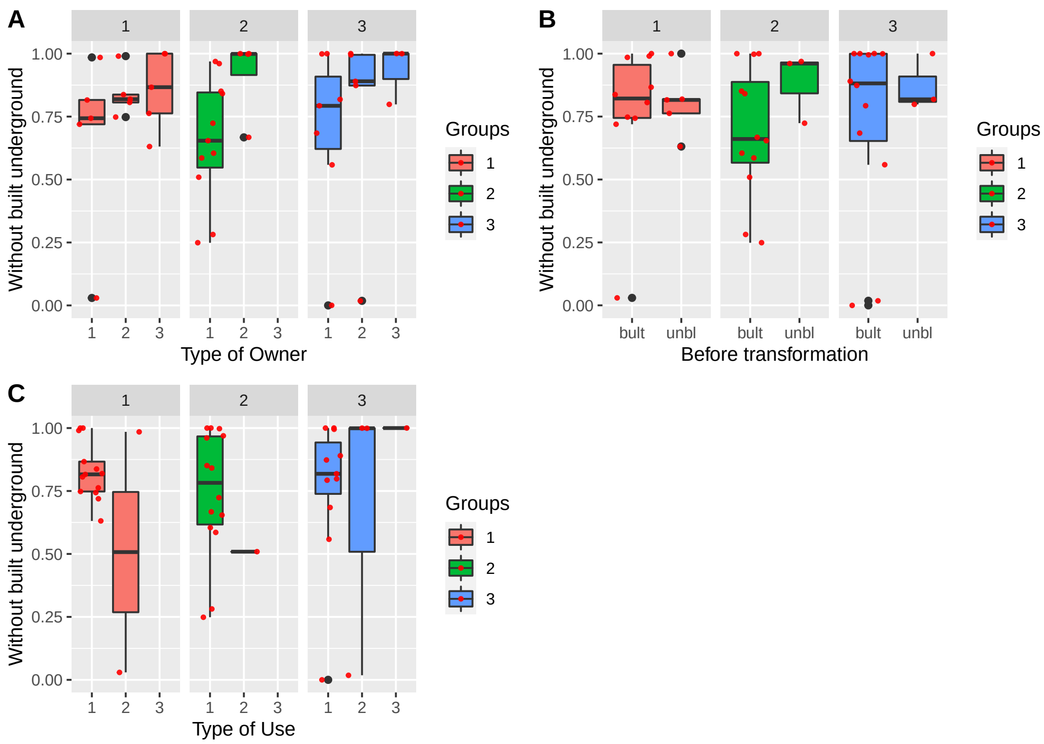

Figure A.11: Grouped Boxplots of *Green Share Without built Underground*.

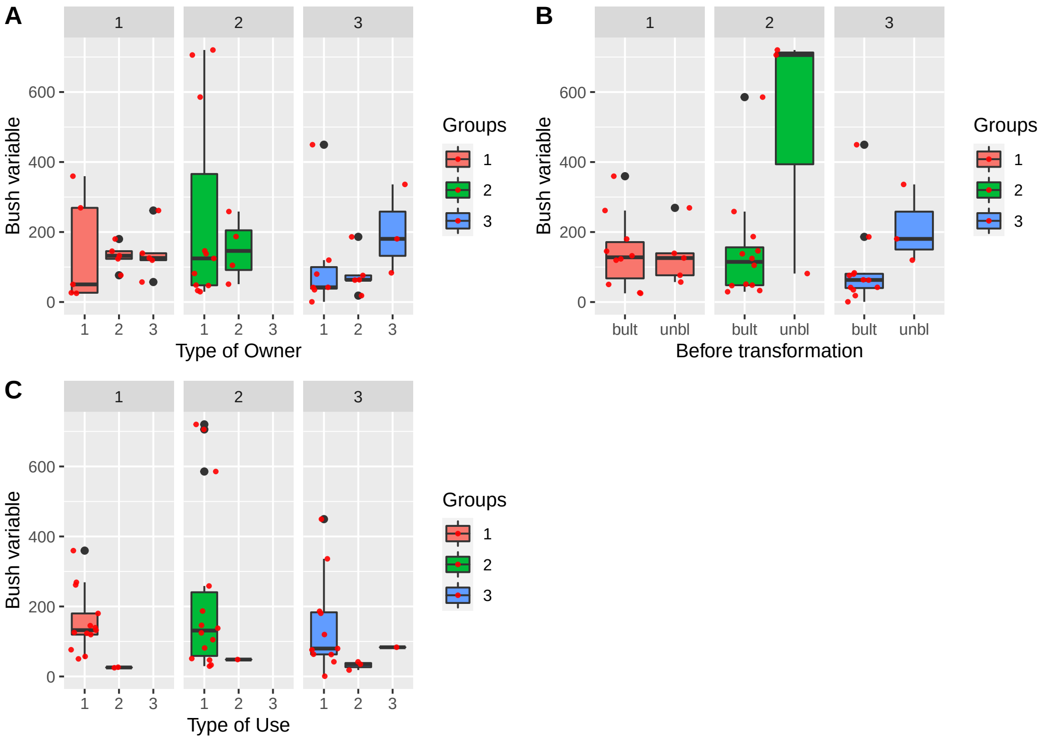

Figure A.12: Grouped Boxplots of *Bush Variable*.

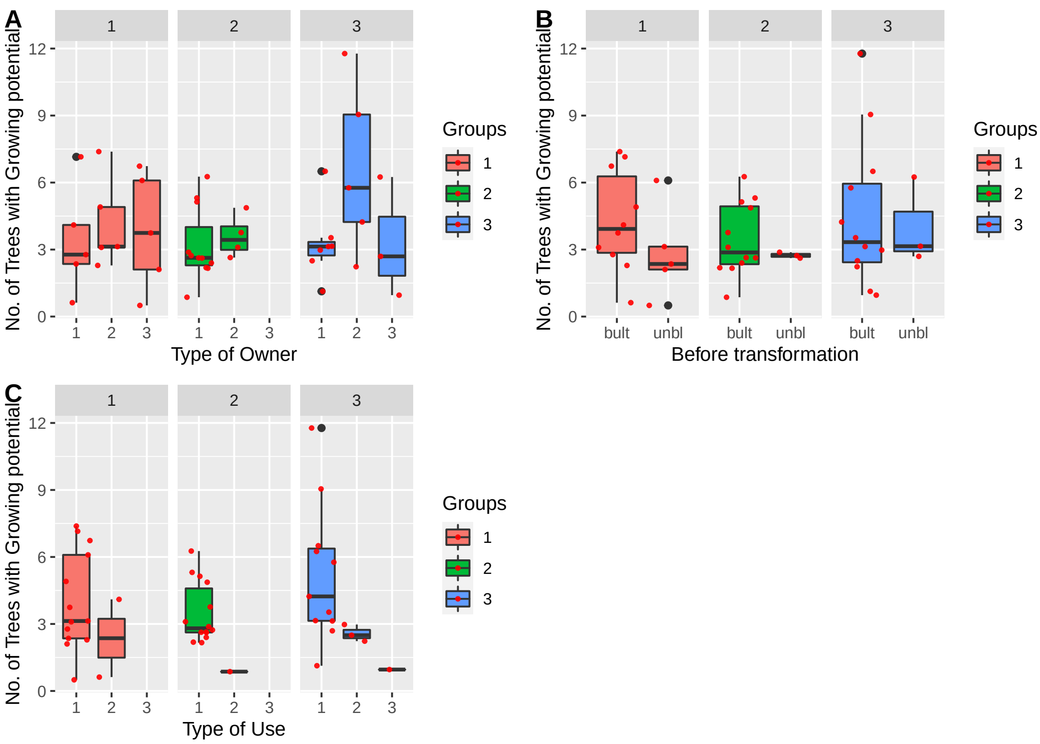

Figure A.13: Grouped Boxplots of *Number of Trees with Growing Potential*.

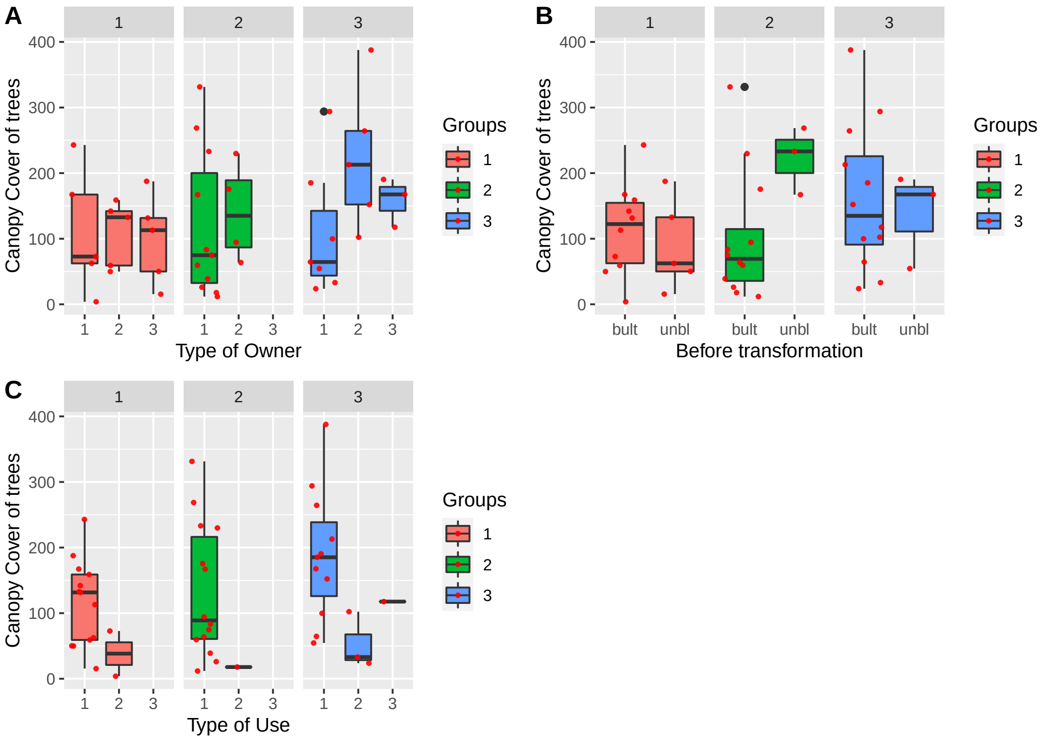

Figure A.14: Grouped Boxplots of *Canopy Cover of Trees*.

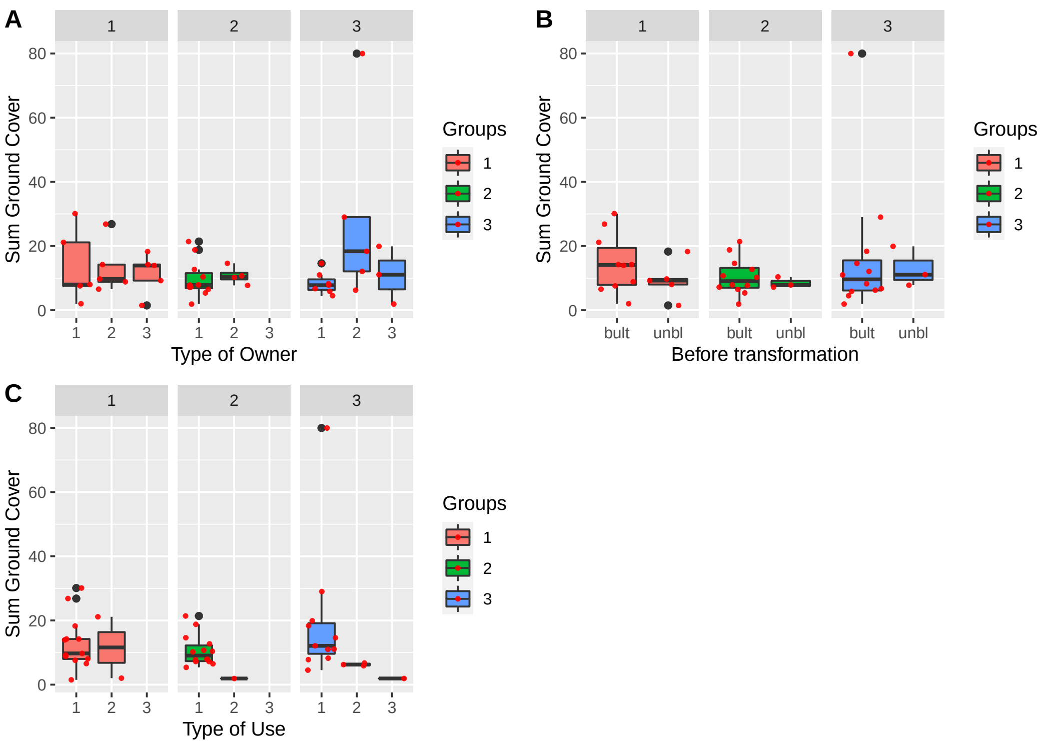

Figure A.15: Grouped Boxplots of *Ground Cover Underneath the Trees (Sum)*.

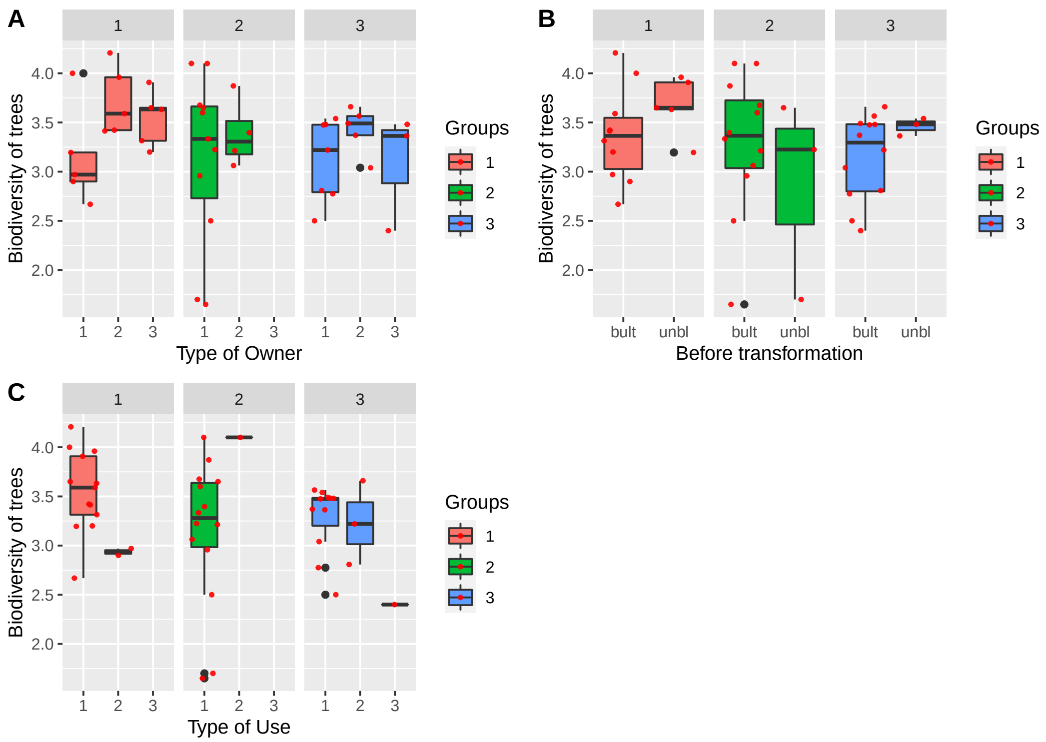

Figure A.16: Grouped Boxplots of *Biodiversity of Trees*.

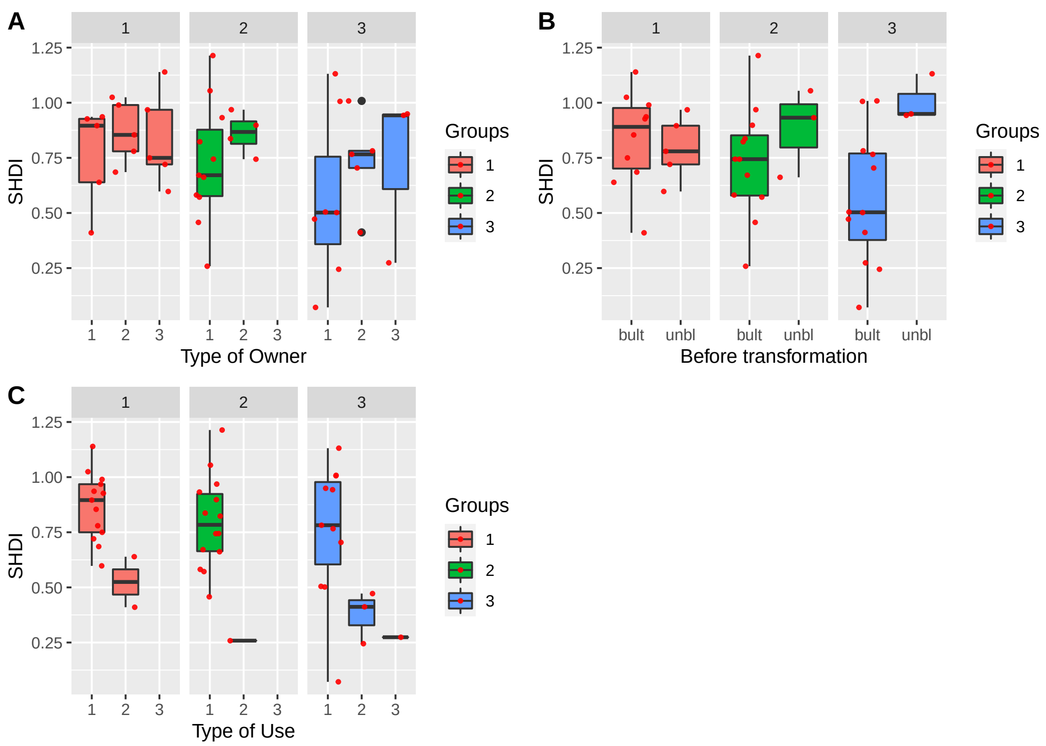

Figure A.17: Grouped Boxplots of *SHDI*.

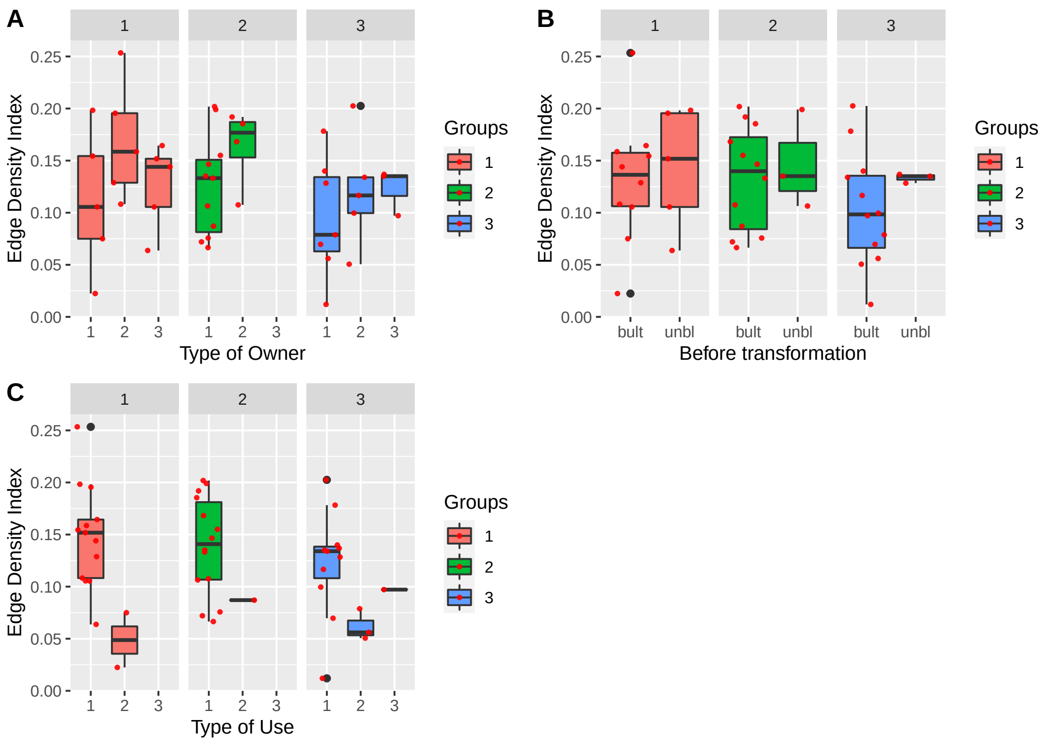

Figure A.18: Grouped Boxplots of *Edge Density Index*.

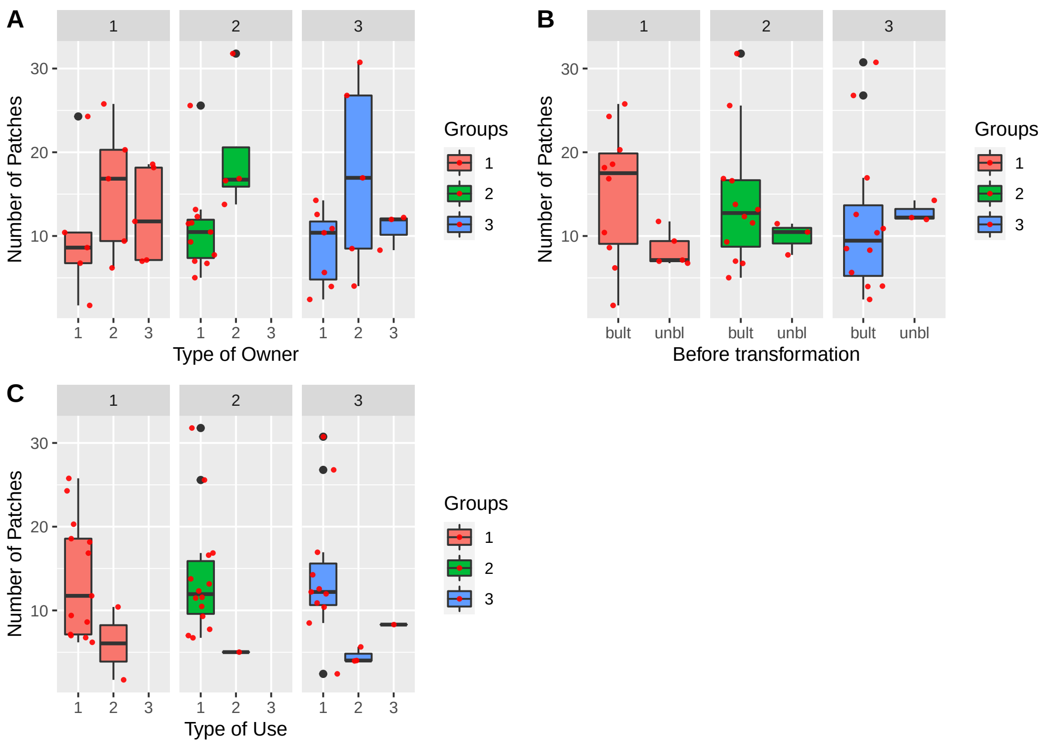

Figure A.19: Grouped Boxplots of *Number of Patches*.

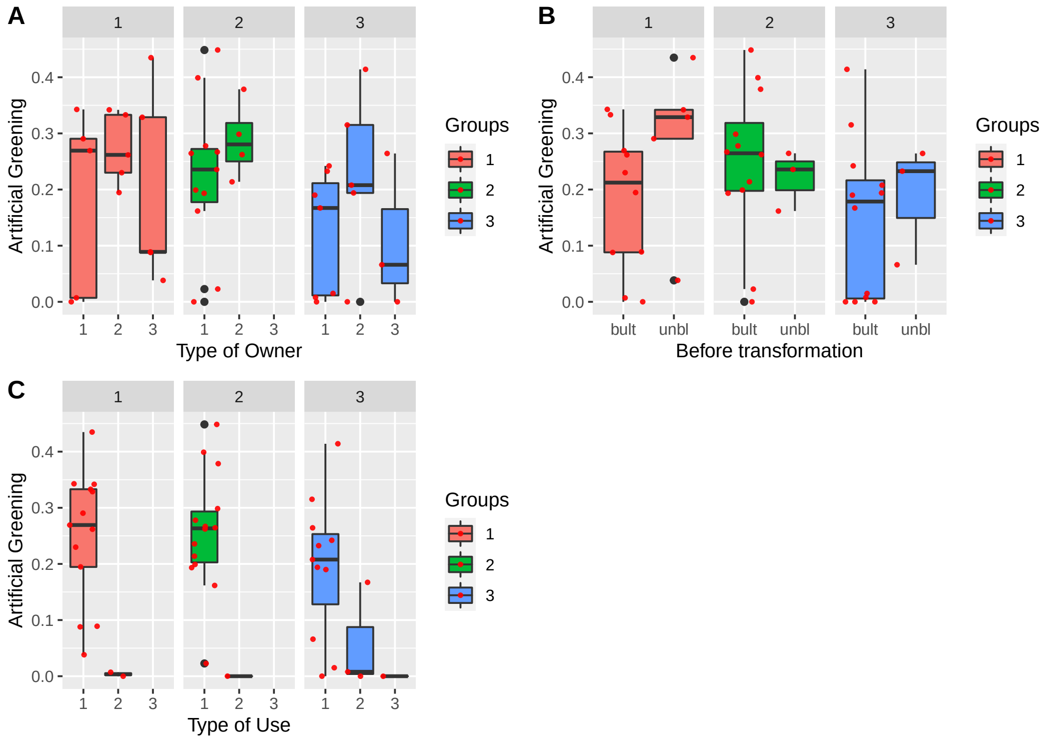

Figure A.20: Grouped Boxplots of *Artificial Greening*.

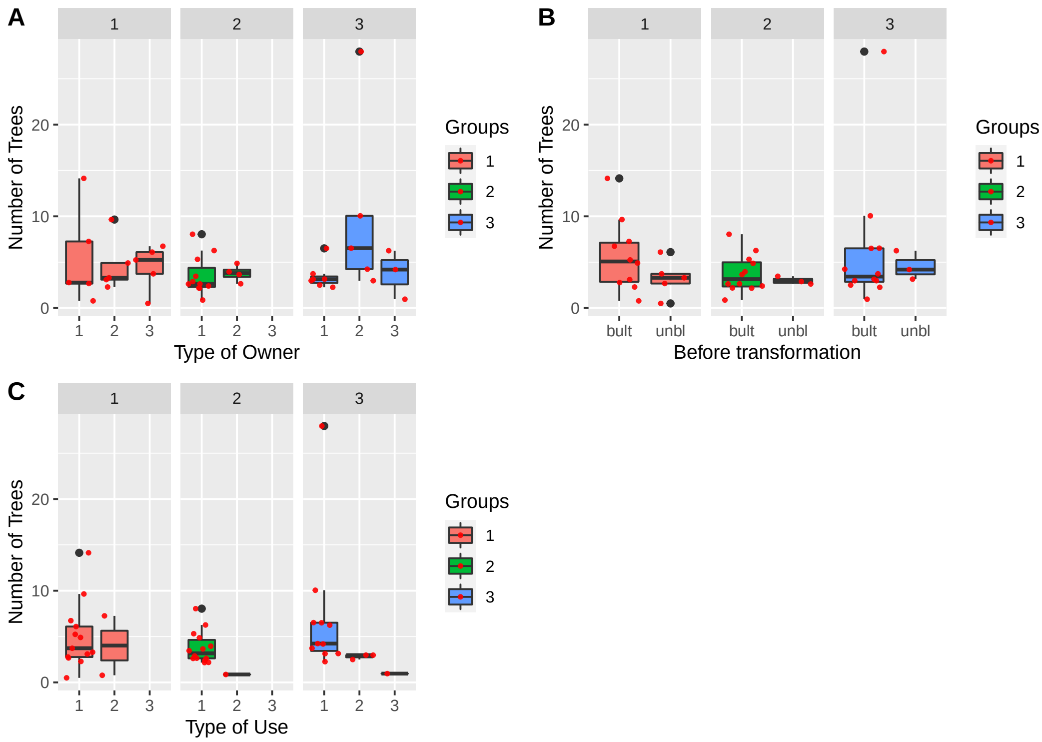

Figure A.21: Grouped Boxplots of *Number of Trees*.

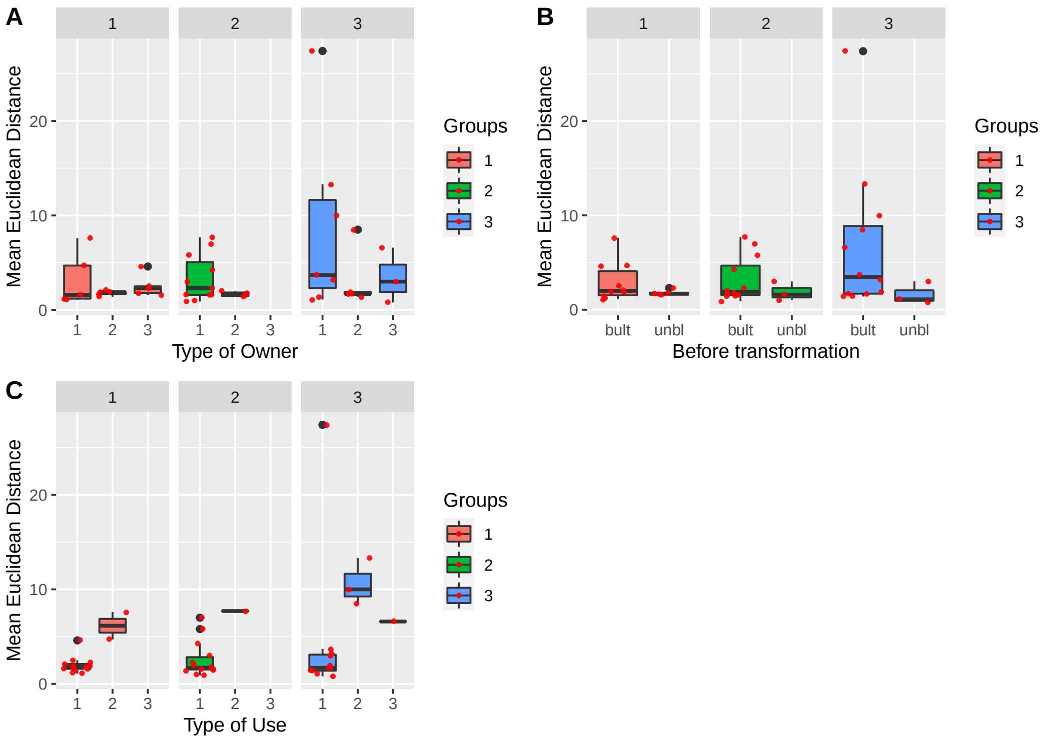

Figure A.22: Grouped Boxplots of *Mean Euclidean Distance*.

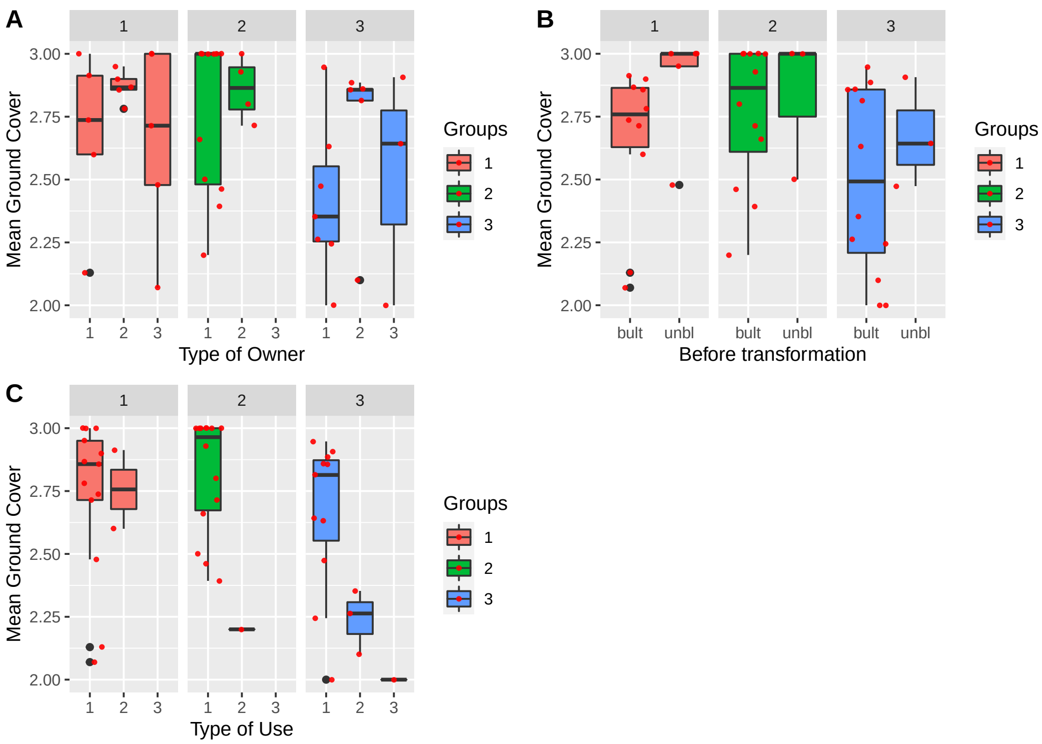

Figure A.23: Grouped Boxplots of *Ground Cover Underneath the Trees (Mean)*.

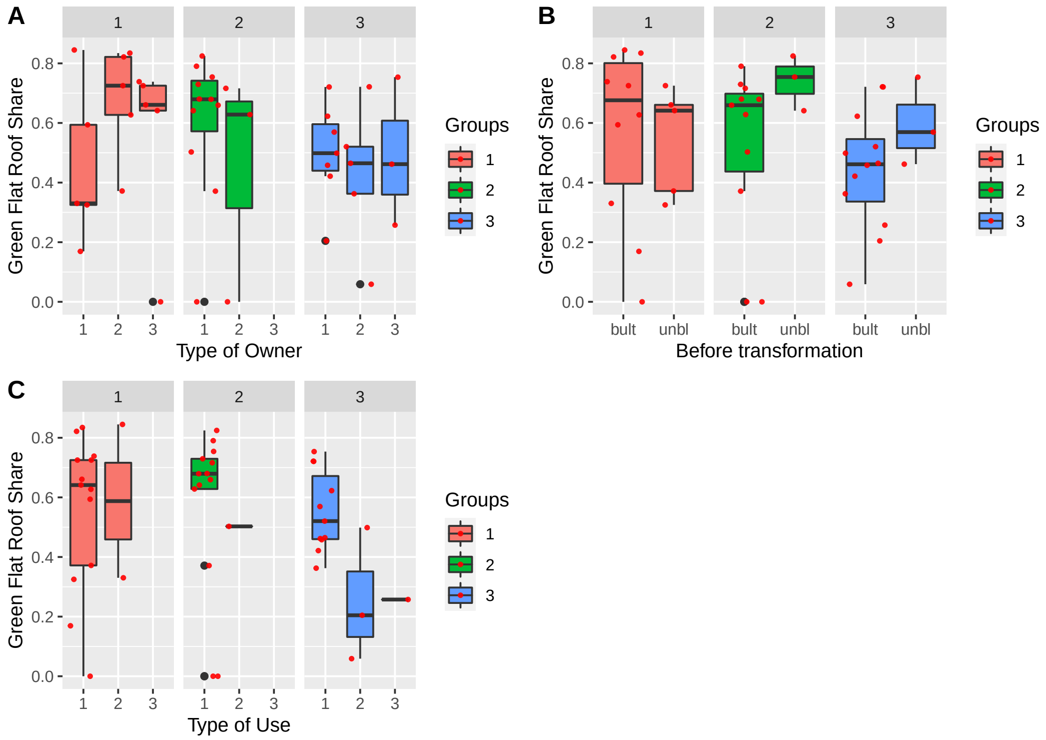

Figure A.24: Grouped Boxplots of *Green Flat Roof Share*.

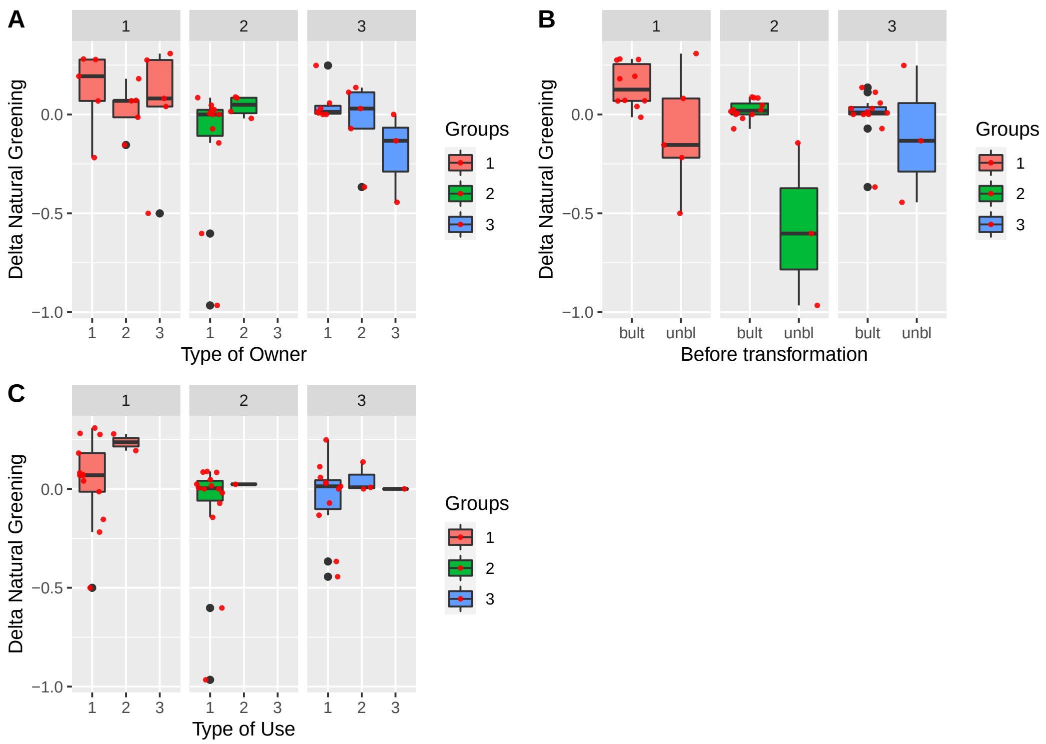

Figure A.25: Grouped Boxplots of Δ *Natural Greening*.

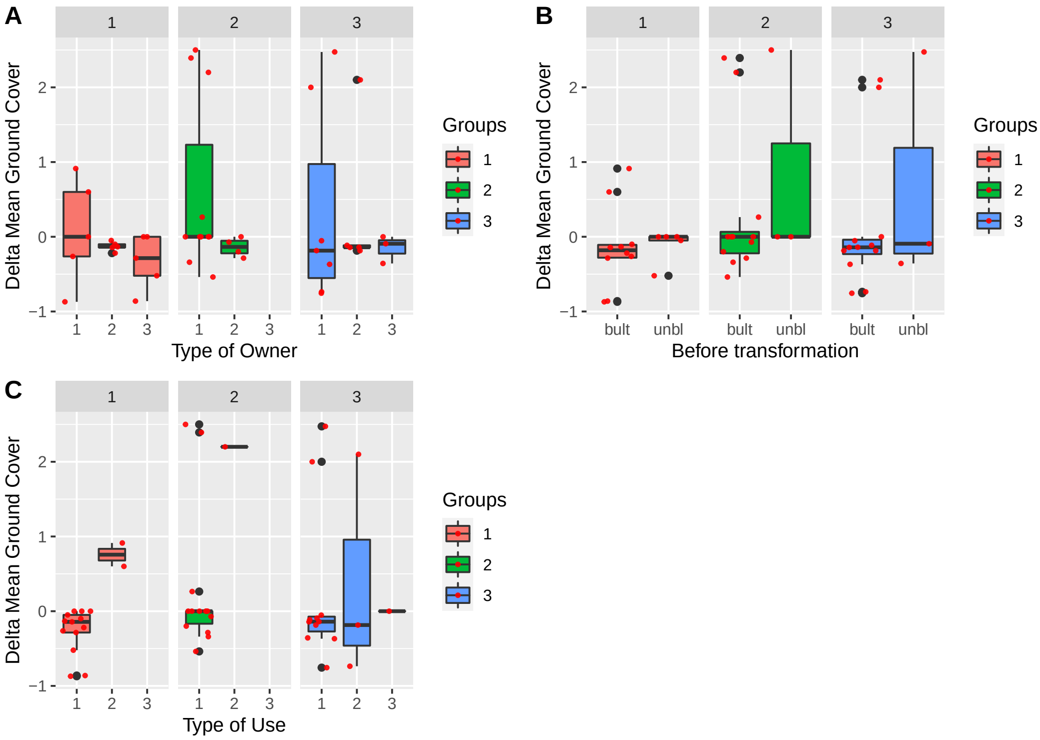

Figure A.26: Grouped Boxplots of Δ *Ground Cover Underneath Trees (Mean)*.

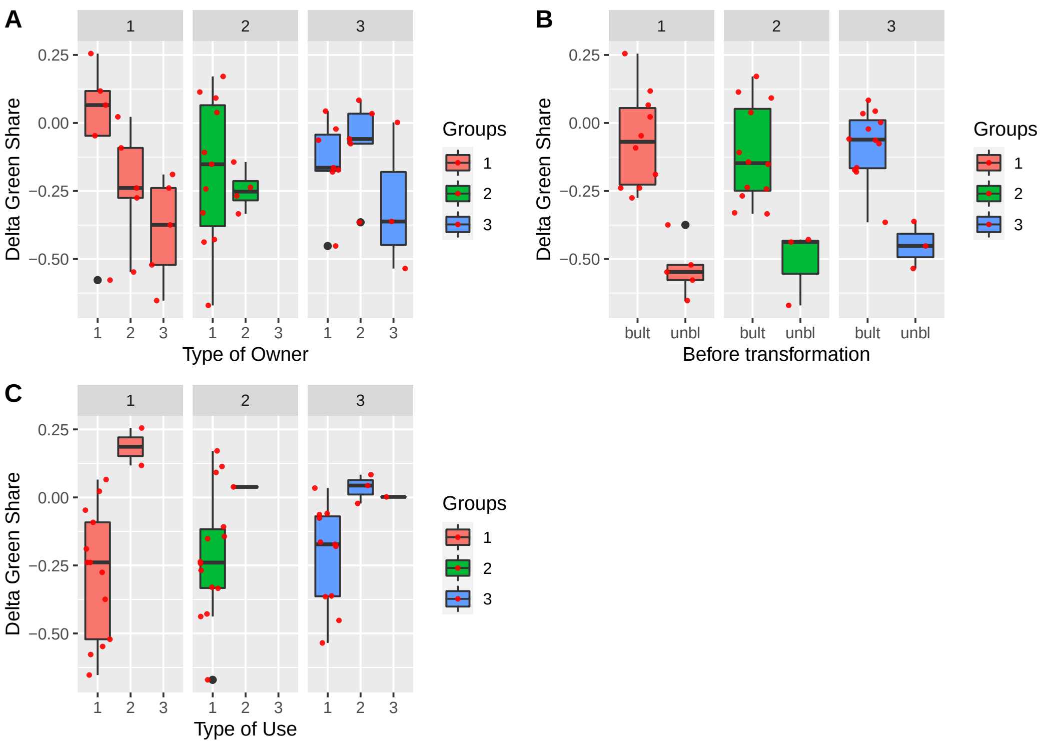

Figure A.27: Grouped Boxplots of Δ *Green Share*.

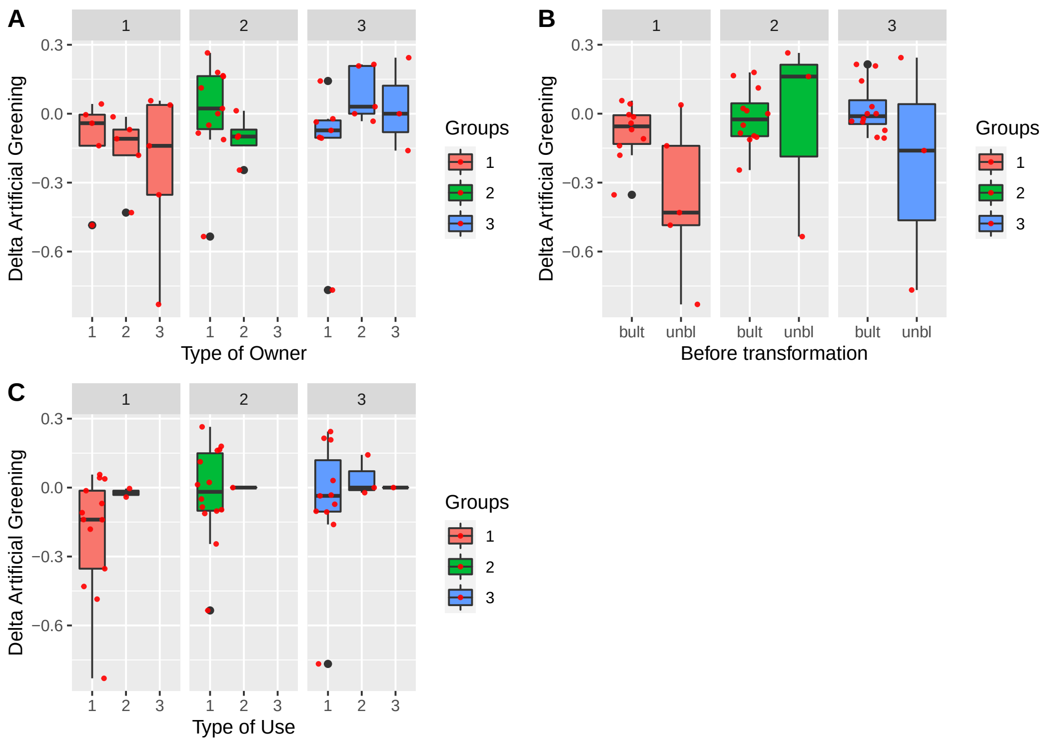

Figure A.28: Grouped Boxplots of Δ *Artificial Greening*.

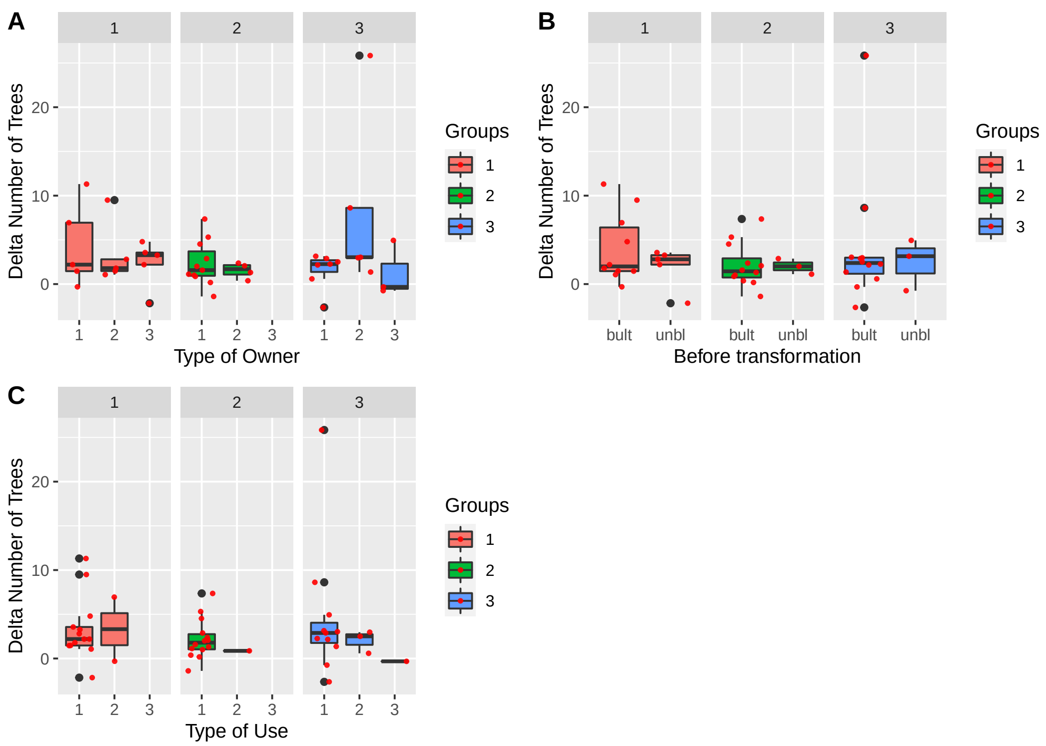

Figure A.29: Grouped Boxplots of Δ *Number of Trees*.

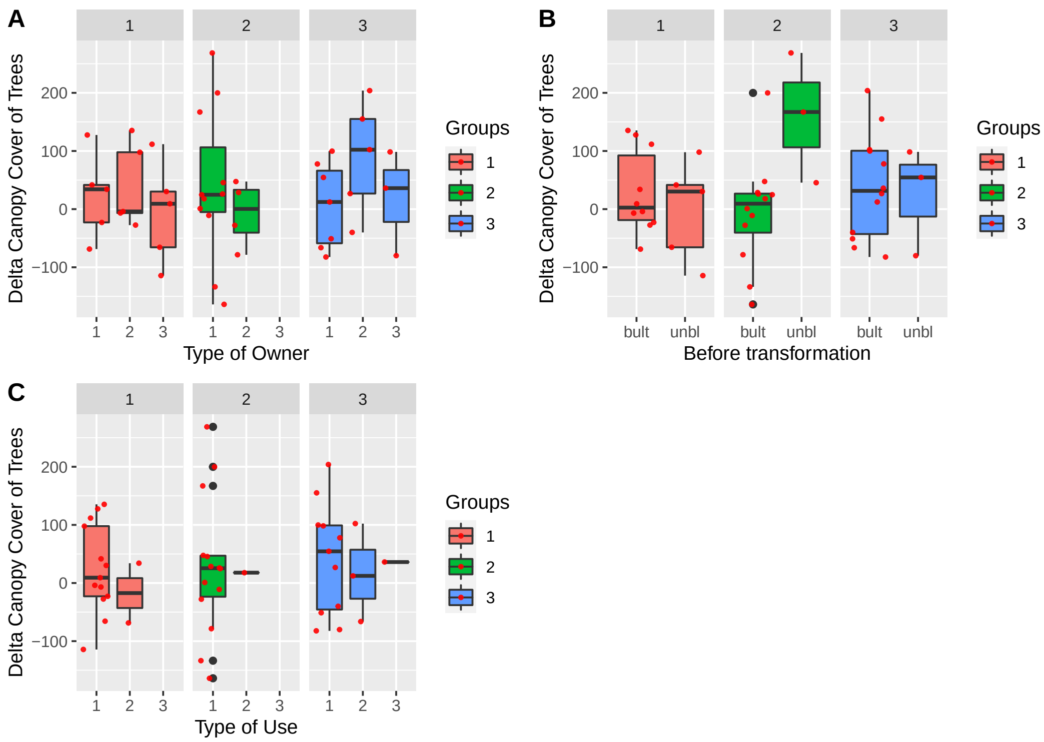

Figure A.30: Grouped Boxplots of Δ *Canopy Cover of Trees.*

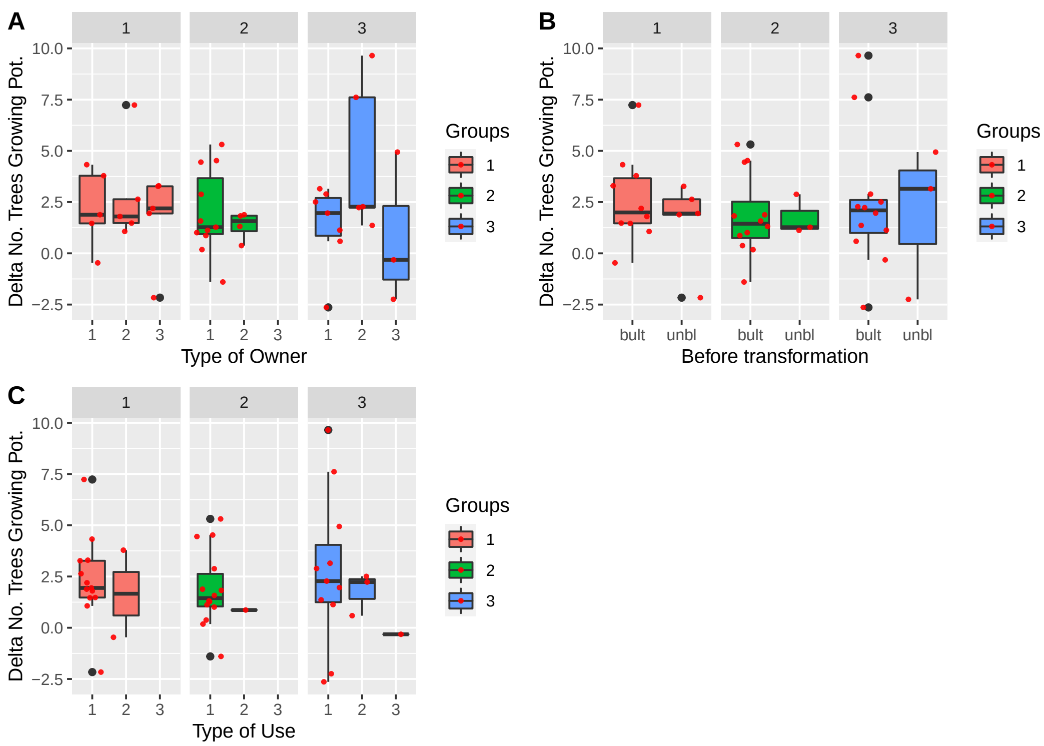

Figure A.31: Grouped Boxplots of Δ *Number of Trees with Growing Potential.*

G Histograms and Normal-QQ-Plots

The Histograms and the Normal-QQ-Plots are computed with the 30 data points of the Group 1 and 2, without the Control Group.

Natural Greening had to be log-transformed to be normally distributed.

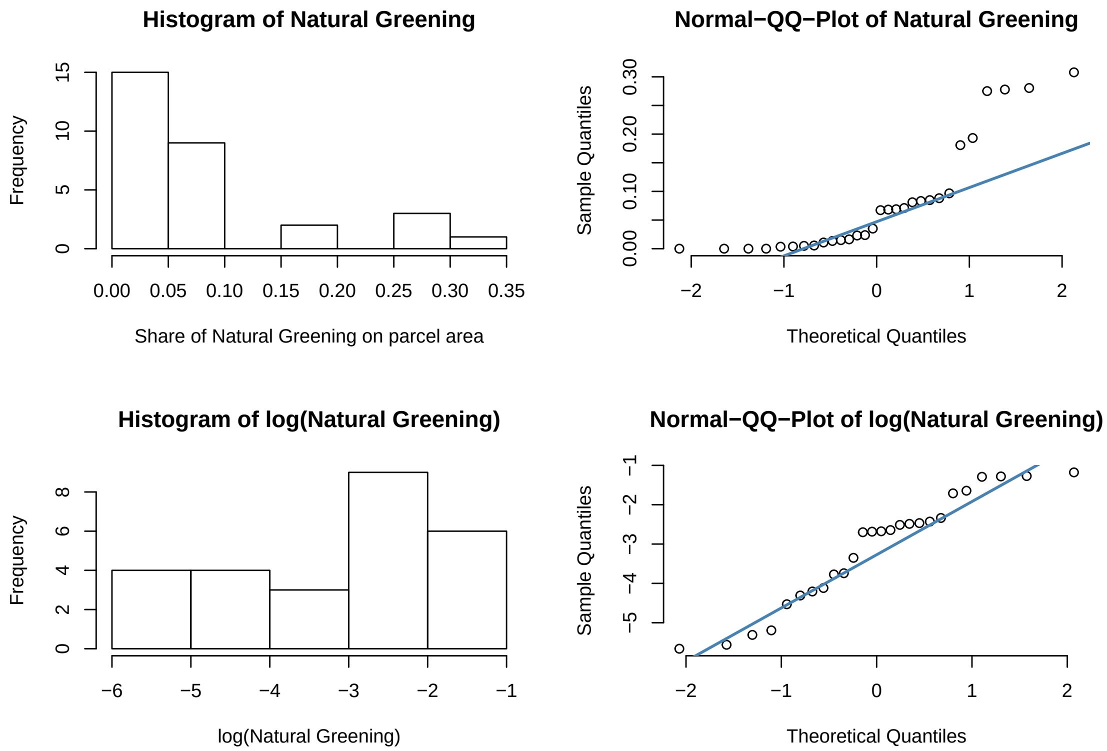

Figure A.32: Histogram and Normal-QQ-Plot of *Natural Greening* and log(*Natural Greening*).

The distribution of *Green Share* was accepted as normally distributed.

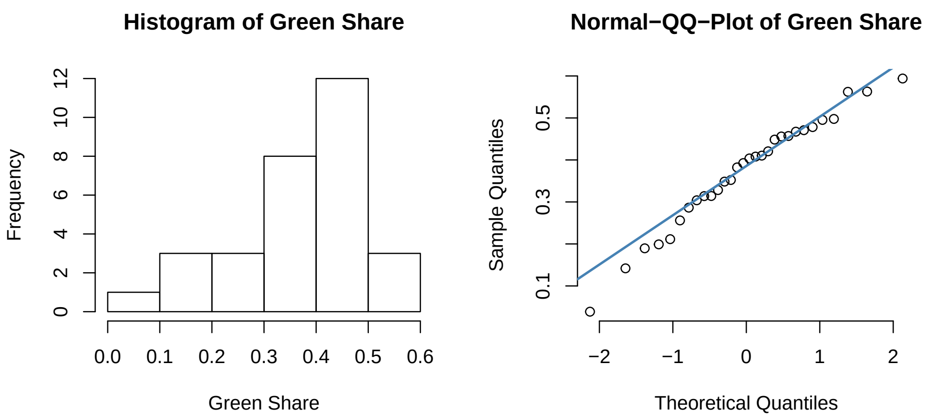

Figure A.33: Histogram and Normal-QQ-Plot of *Green Share*.

Green Share Without Built Underground had to undergo a $log(x/(1-x))$-transformation. The *Bush Variable* was log-transformed.

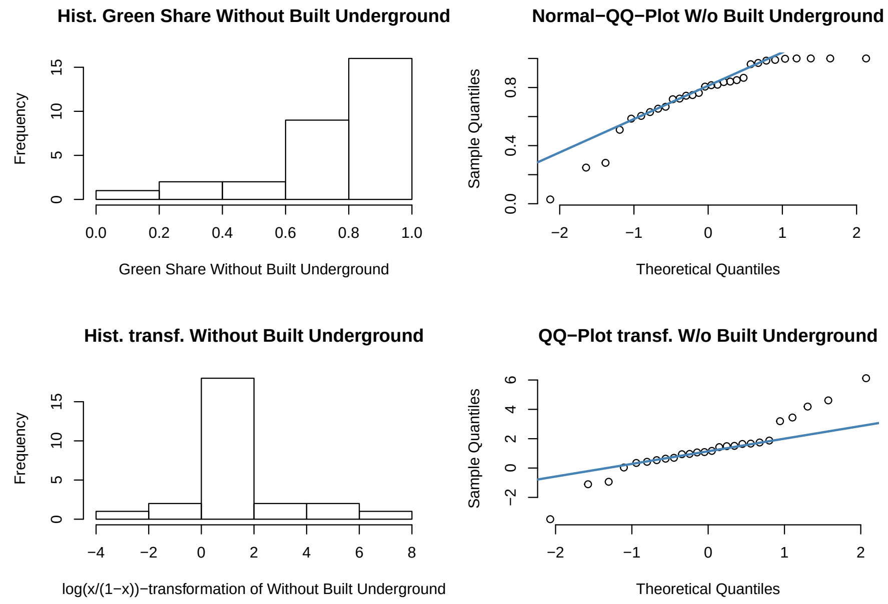

Figure A.34: Histogram and Normal-QQ-Plot of *Green Share Without Built Underground* and the $log(x/(1-x))$-transformation.

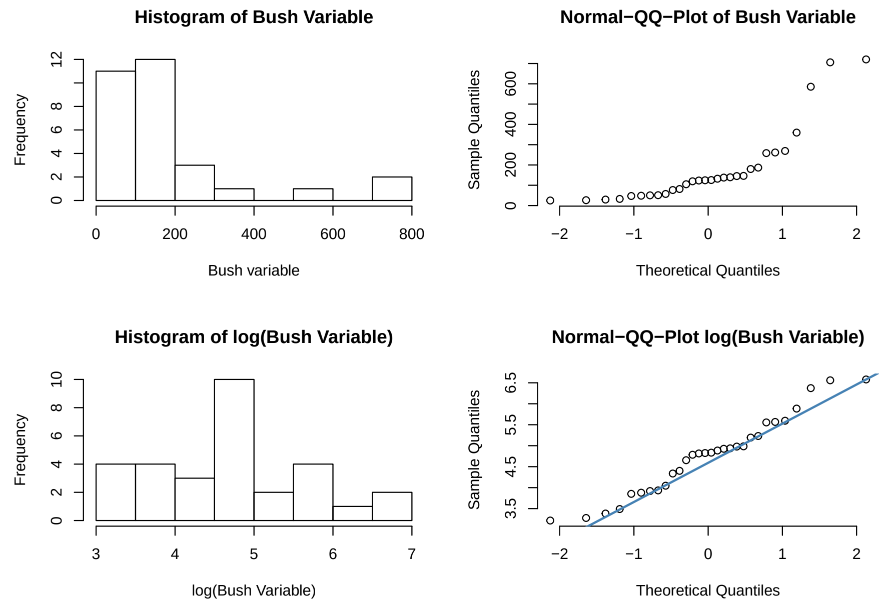

Figure A.35: Histogram and Normal-QQ-Plot of *Bush Variable* and log(*Bush Variable).*

The *Number of Trees with Growing Potential* as well as the *Canopy Cover of Trees* were accepted as normally distributed.

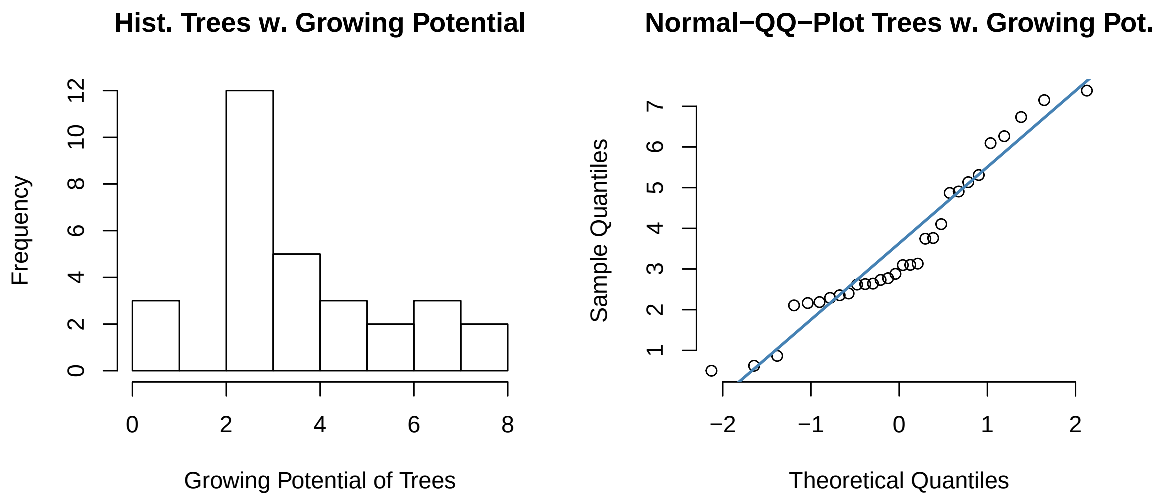

Figure A.36: Histogram and Normal-QQ-Plot of *Number of Trees with Growing Potential*.

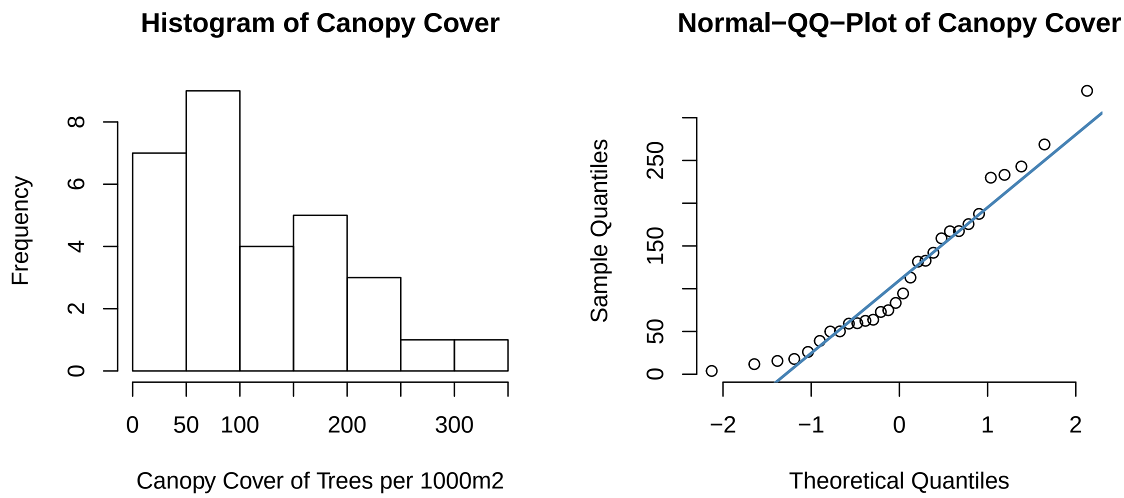

Figure A.37: Histogram and Normal-QQ-Plot of *Canopy Cover of Trees*.

Ground Cover Underneath the Trees (Sum) was log-transformed to achieve a normal distribution. *Biodiversity of Trees* was accepted as a normal distribution without a transformation.

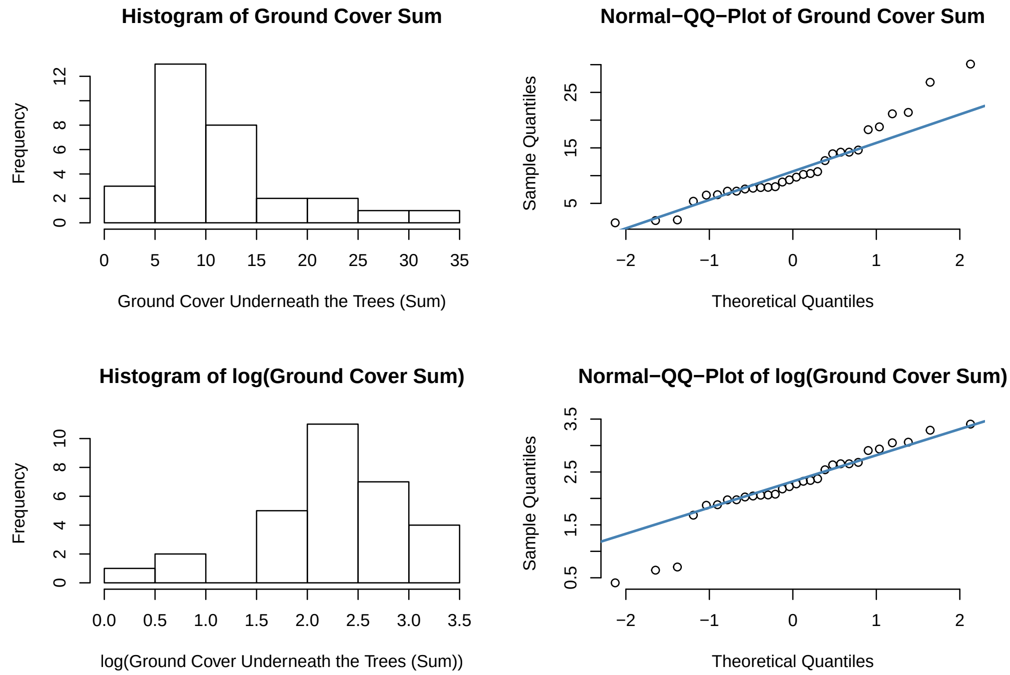

Figure A.38: Histogram and Normal-QQ-Plot of *Ground Cover Underneath Trees (Sum)* and the log-transformation.

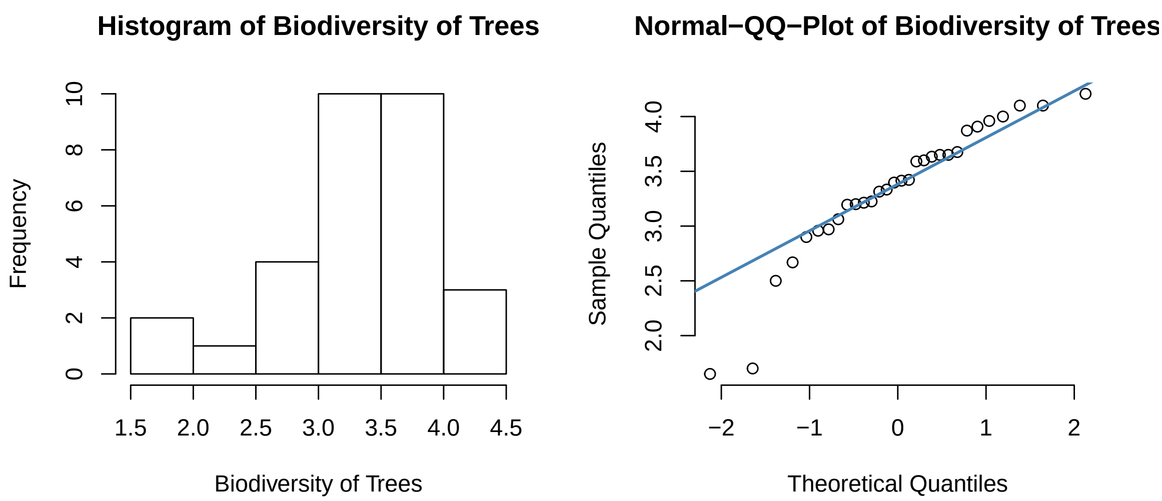

Figure A.39: Histogram and Normal-QQ-Plot of *Biodiversity of Trees*.

The *SHDI* as well as the *Edge Density Index* are normally distributed.

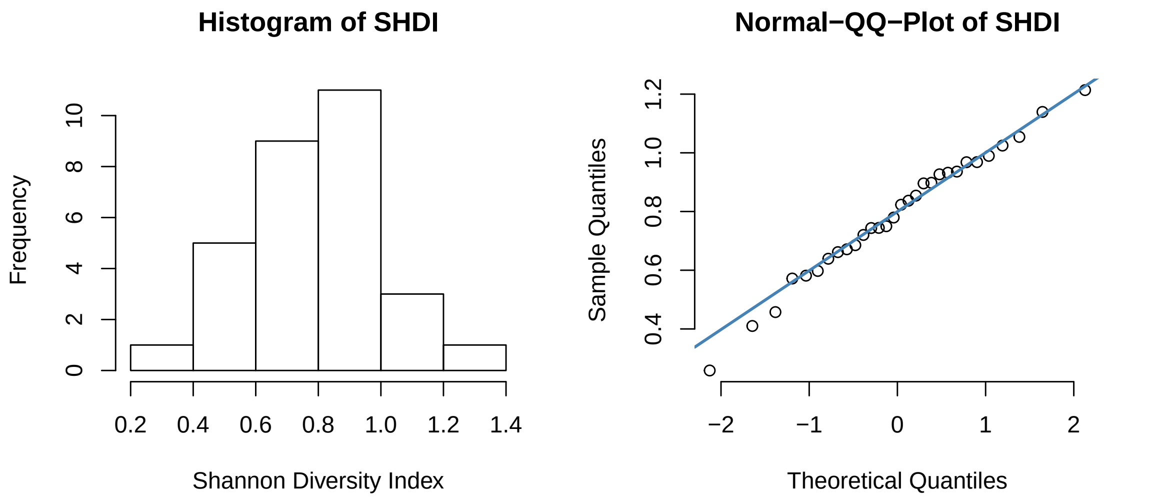

Figure A.40: Histogram and Normal-QQ-Plot of *SHDI*.

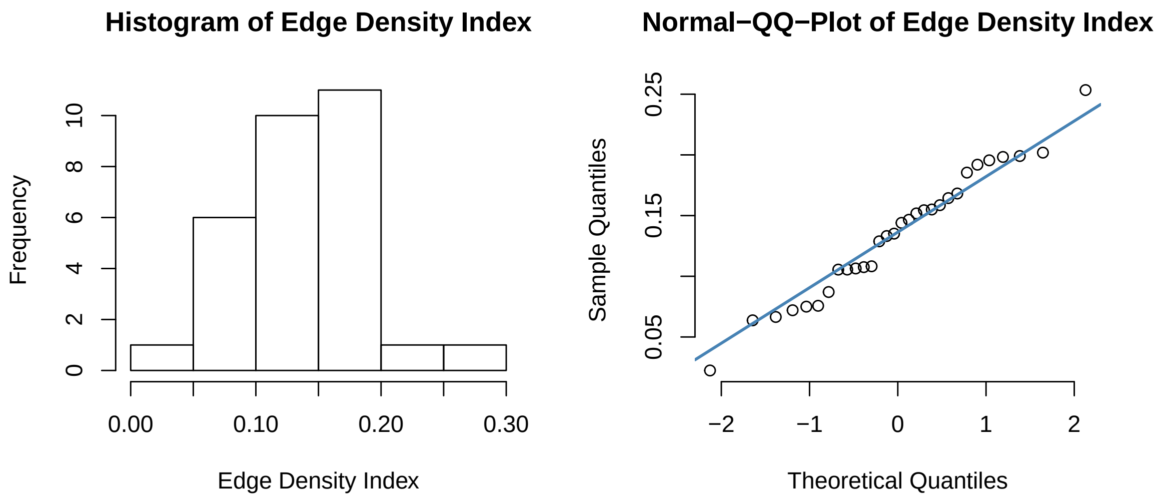

Figure A.41: Histogram and Normal-QQ-Plot of *Edge Density Index*.

The *Number of Patches* as well as the *Artificial Greening* are normally distributed.

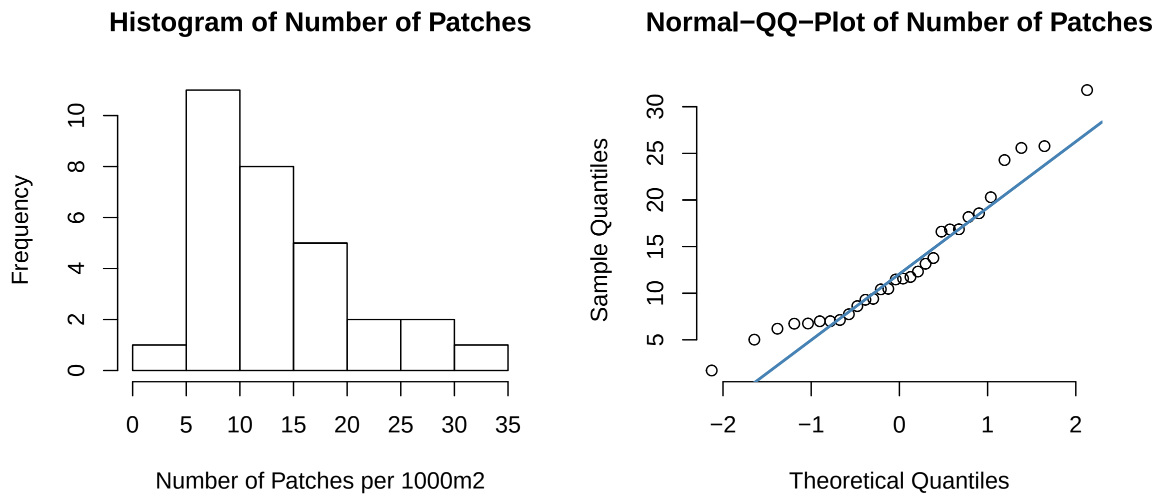

Figure A.42: Histogram and Normal-QQ-Plot of *Number of Patches*.

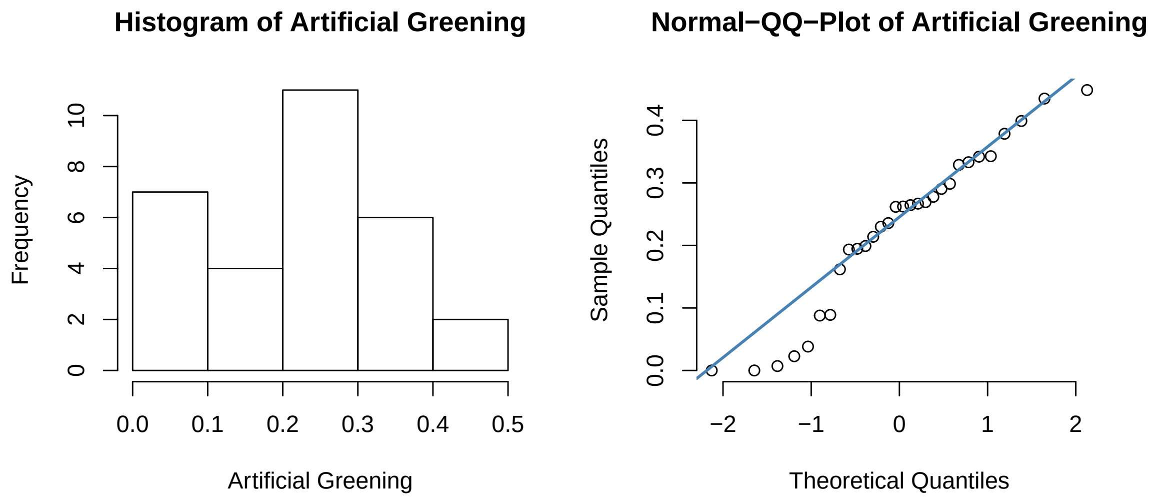

Figure A.43: Histogram and Normal-QQ-Plot of *Artificial Greening*.

The variable *Number of Trees* had to be log-transformed after removing the outliers on the top of the spectrum (> 20) to achieve a normal distribution. The *Mean Euclidean Distance* was accepted as normally distributed as the Shapiro-Wilk Test confirmed it.

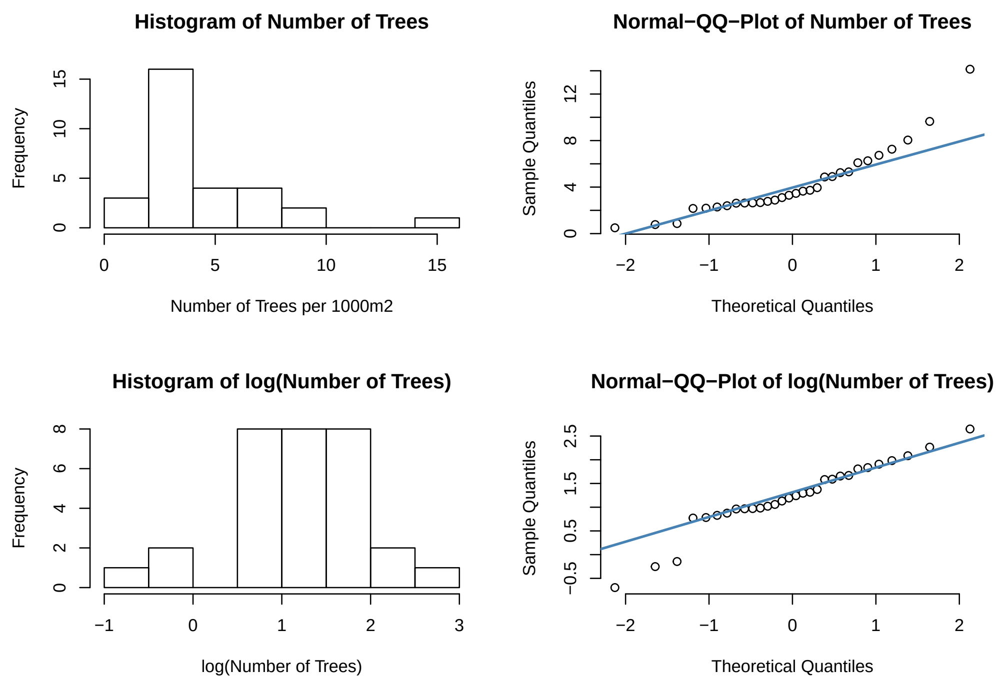

Figure A.44: Histogram and Normal-QQ-Plot of *Number of Trees* and the log-transformation.

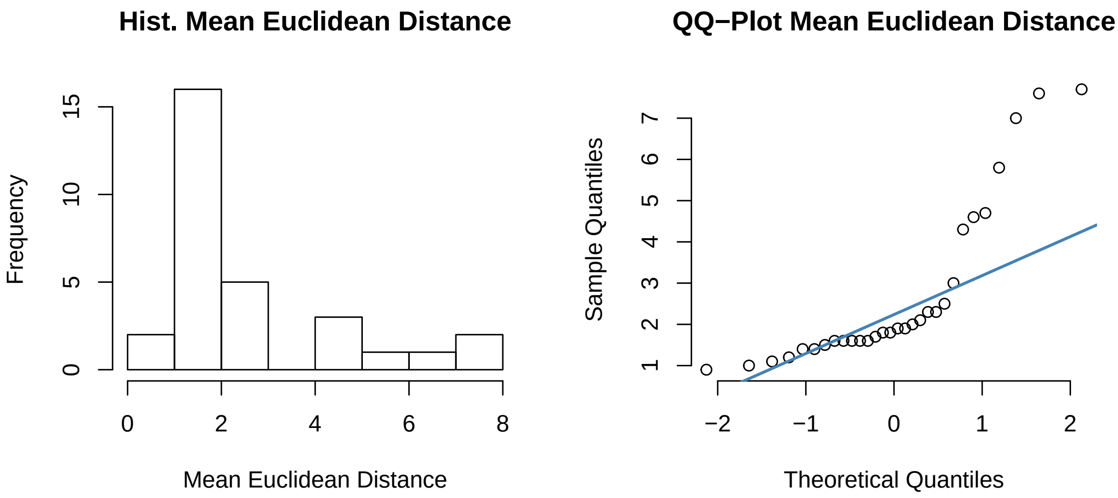

Figure A.45: Histogram and Normal-QQ-Plot of *Mean Euclidean Distance*.

The *Ground Cover Underneath the Trees (Mean)* is not normally distributed, but it was not transformed as it was not used in further analysis. The same accounts for *Green Flat Roof Share*

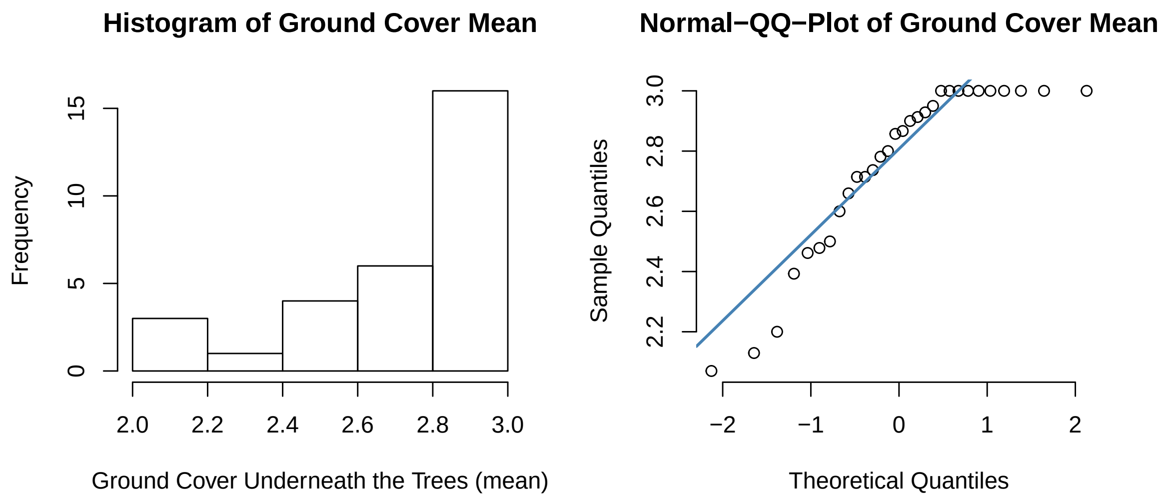

Figure A.46: Histogram and Normal-QQ-Plot of *Ground Cover Underneath the Trees (Mean)*.

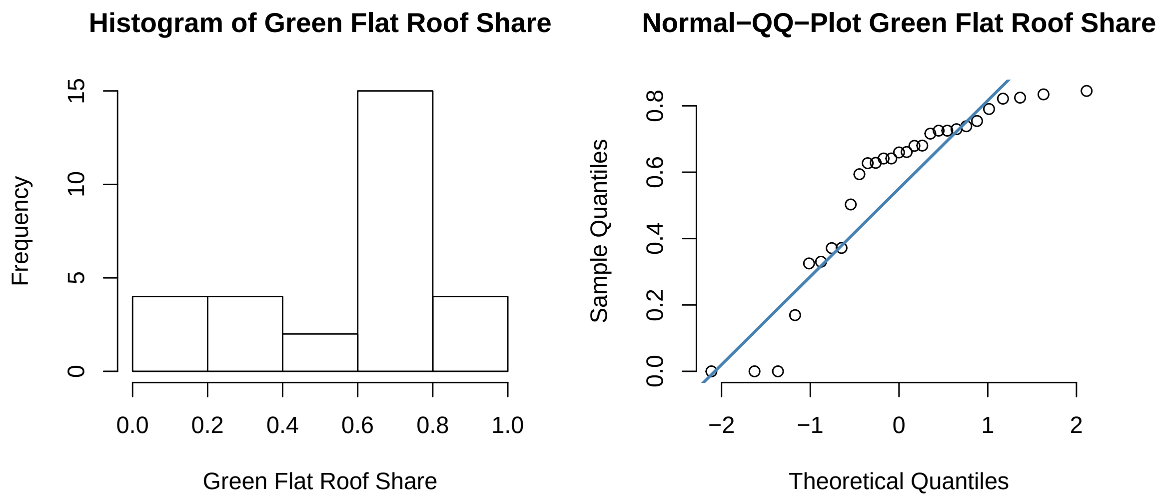

Figure A.47: Histogram and Normal-QQ-Plot of *Green Flat Roof Share*.

The variables Δ *Natural Greening* and Δ *Ground Cover Underneath the Trees (Mean)* were not normally distributed and neglected from the analysis.

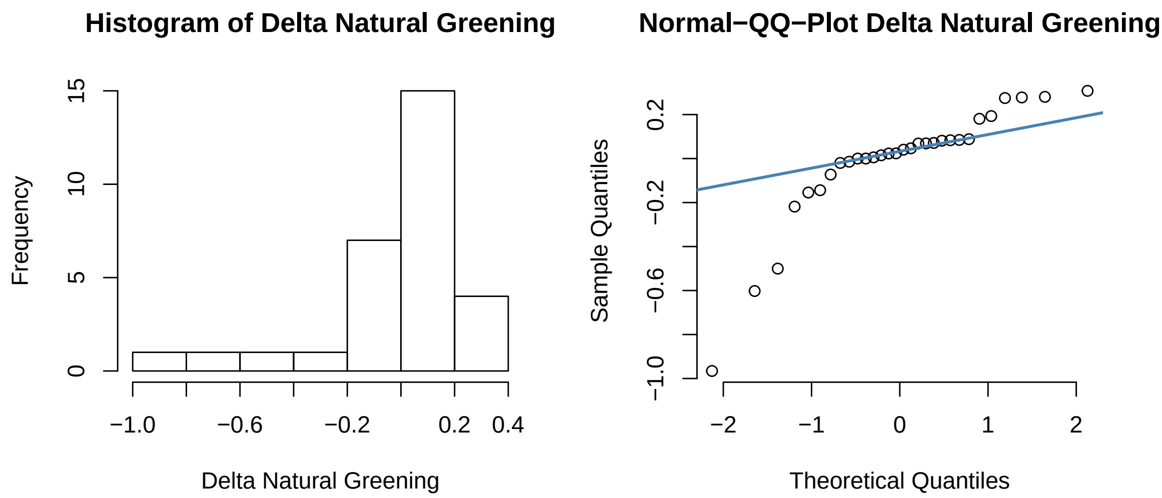

Figure A.48: Histogram and Normal-QQ-Plot of Δ *Natural Greening*.

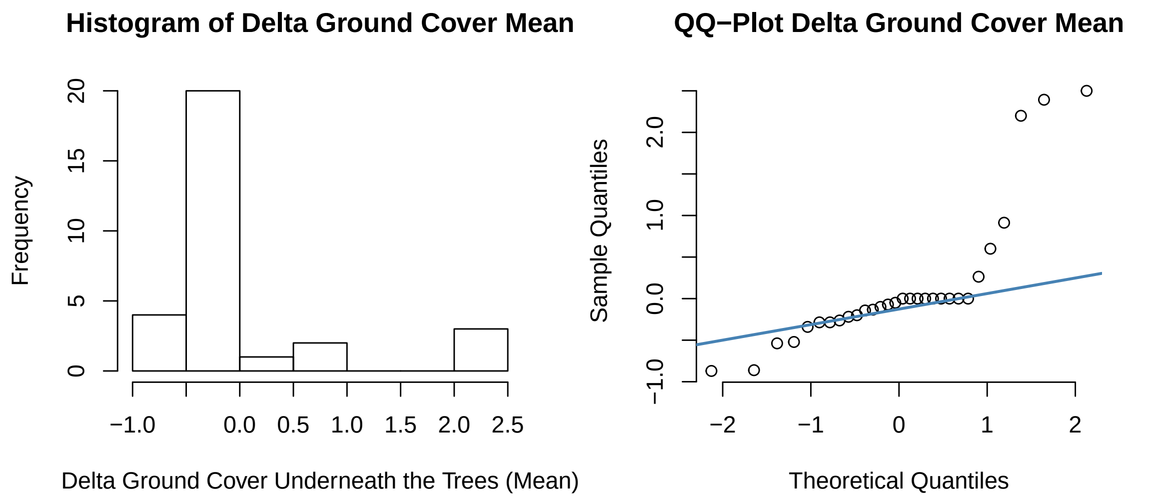

Figure A.49: Histogram and Normal-QQ-Plot of Δ *Ground Cover Underneath the Trees (Mean)*.

Δ *Green Share* and Δ *Artificial Greening* are normally distributed.

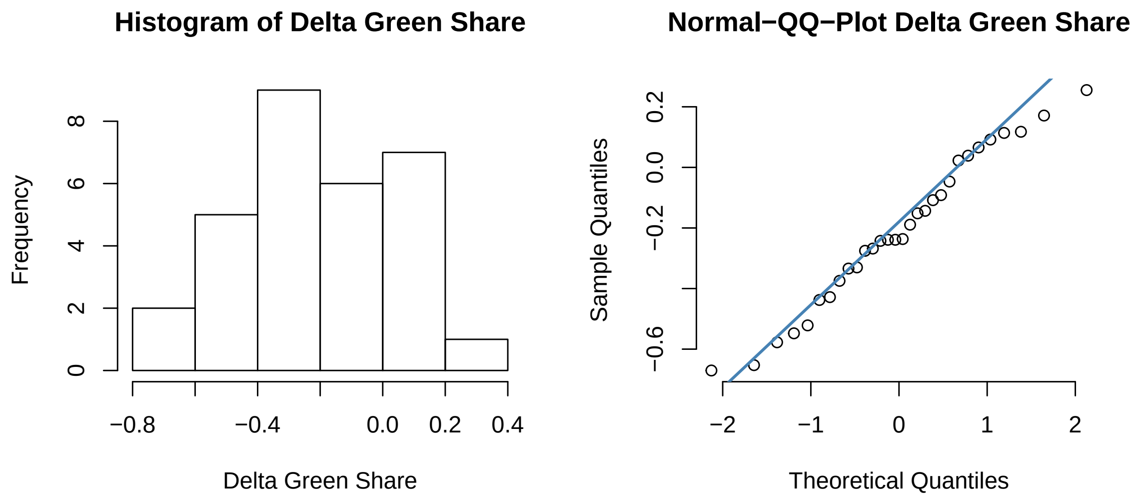

Figure A.50: Histogram and Normal-QQ-Plot of Δ *Green Share*.

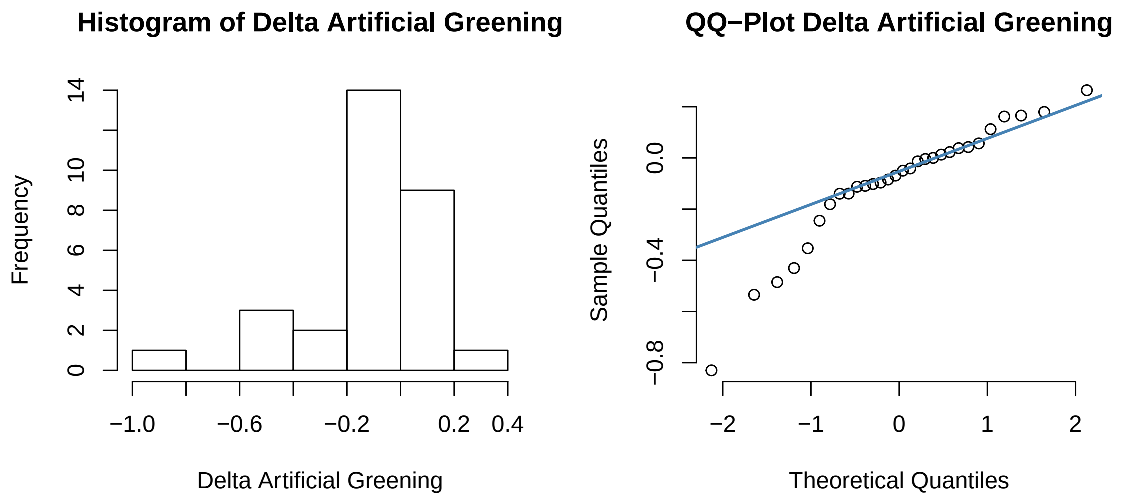

Figure A.51: Histogram and Normal-QQ-Plot of Δ *Artificial Greening*.

Δ *Number of Trees* and Δ *Canopy Cover of Trees* are normally distributed.

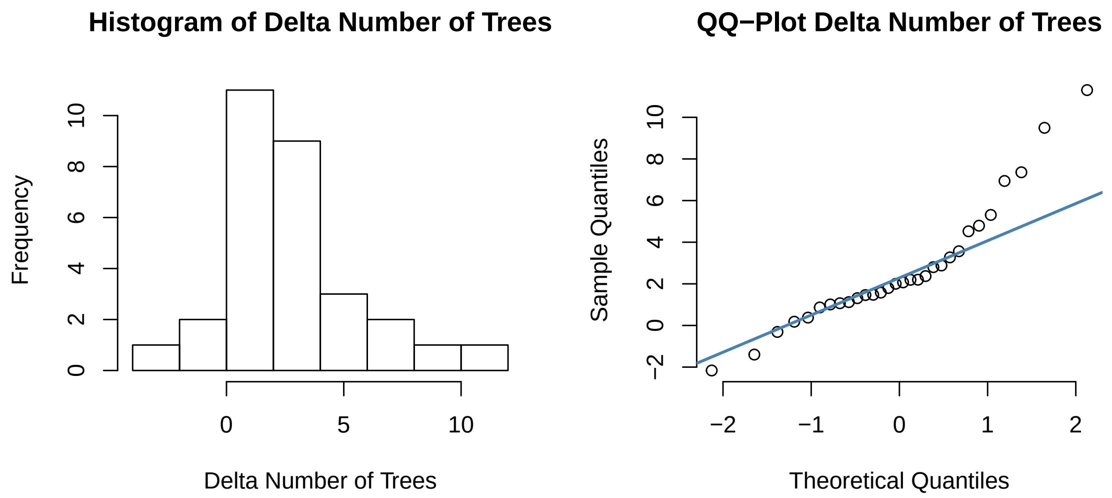

Figure A.52: Histogram and Normal-QQ-Plot of Δ *Number of Trees*.

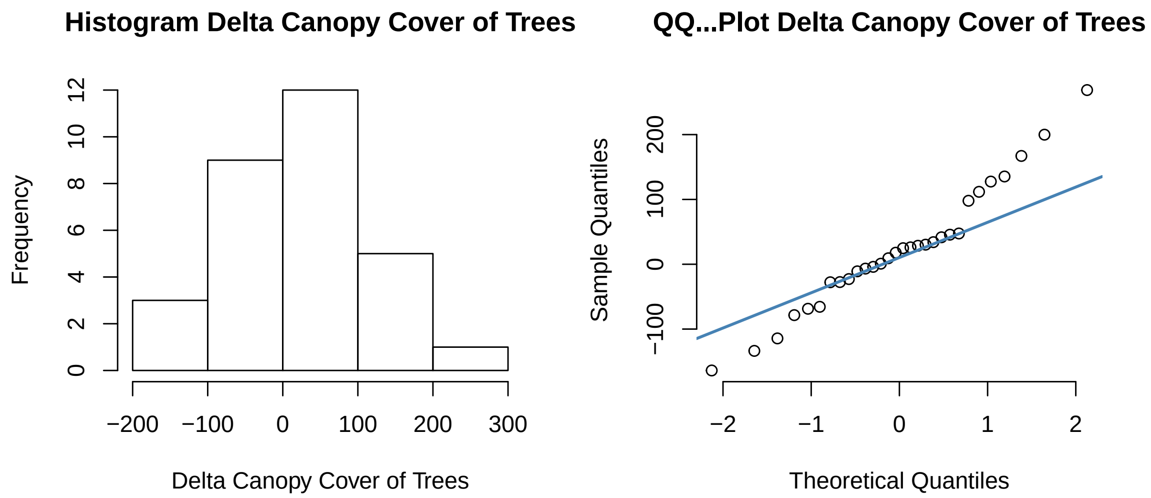

Figure A.53: Histogram and Normal-QQ-Plot of Δ *Canopy Cover of Trees*.

Δ *Number of Trees with Growing Potential* is normally distributed.

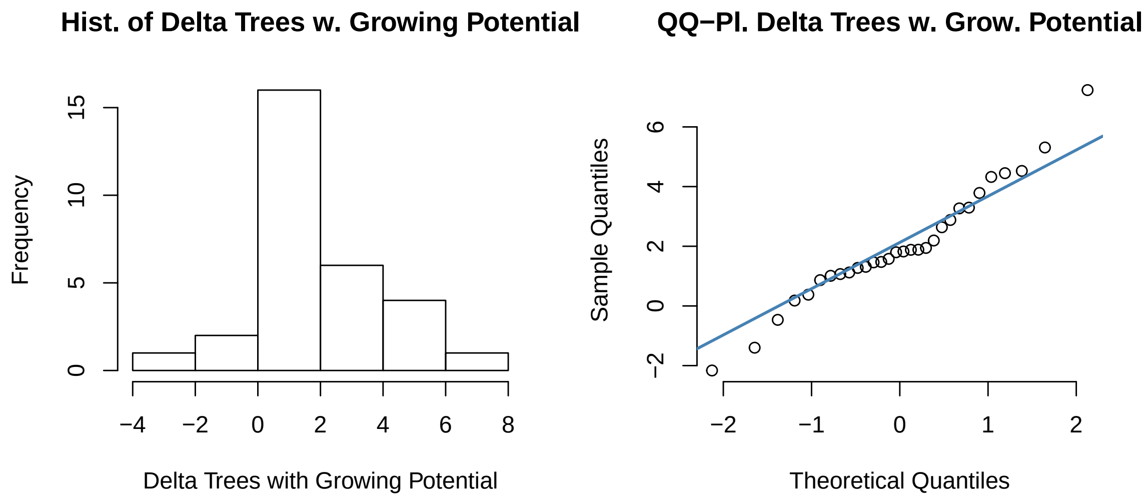

Figure A.54: Histogram and Normal-QQ-Plot of Δ *Number of Trees with Growing Potential.*

H Interview Guiding Questions

Introduction

- Kurze Erklärung zu meiner Masterarbeit
- Organisatorisches
  - Ist es für Sie in Ordnung, wenn ich dieses Gespräch aufzeichne?
  - Zitate werden vor Gebrauch vorgelegt zur Absegnung.
  - Soll ich Sie anonym zitieren?
- Erste Resultate nach dem Interview
  - Kaum Unterschiede zwischen AÜ und den anderen Gruppen.
  - Einzelne Aspekte zeigen Unterschiede (natürliches Grün)
  - Sonst eher variabel; Mischnutzung weniger Grün als reine Wohnnutzung

Interview AfS "Unit for Architecture and Urban Space"

- Was ist Ihre Rolle beim Amt für Städtebau?
- Wie ist der Ablauf bei einem Baugesuch mit *Arealüberbauungen*?
- Wie häufig gibt es Baugesuche mit *Arealüberbauungen*?
- Was sind Ihrer Meinung nach die Gründe gegen eine *Arealüberbauung*? (Kosten?)
- Ist es zulässig, die Grünräume einer *Arealüberbauung* der Öffentlichkeit unzugänglich zu machen?
- Zum Schwellenwert von 6000m2: Weshalb wurde genau diese Zahl gewählt?
- Gibt es schon Ideen, wie die *Arealüberbauungen* weiterentwickelt werden sollen?
- Können Sie mir noch weitere Personen für ein Interview empfehlen, die sich häufig mit *Arealüberbauungen* beschäftigen? Jemand von Grün Stadt Zürich, ein Planungsbüro?
- Sind Sie daran interessiert, dass ich Ihnen meine Arbeit nach Abschluss zusende?

Interview AfS "Unit Area Developments and Planning"

- Was ist Ihre Rolle bei der Fachstelle für Arealentwicklungen? Wie gross sind die durchschnittlichen Areale, die sie betreuen?
- Welche Instrumente spielen die grösste Rolle bei der Verdichtung in Zürich? Bei welchen hat die Stadt die grösste Hebelwirkung?
- Welche Rolle spielt die ökologische Qualität bei der Verdichtung/bei Arealentwicklungen? Wie hat sich das entwickelt?
- Wie wird die ökologische Qualität in der Beurteilung von Baugesuchen beachtet?
- Hatten Sie selber schon mit *Arealüberbauungen* zu tun?
- Welche Rolle spielen *Arealüberbauungen* bei der Verdichtung der Stadt Zürich?

- Wie entstand die Grenze von 6000m2?
- Fällt Ihnen noch etwas wichtiges zum Thema Ökologische Qualität bei *Arealüberbauungen* ein, das ich bisher nicht angesprochen habe?
- Sind Sie daran interessiert, dass ich Ihnen meine Arbeit nach Abschluss zusende?

Interview GSZ "Unit for Open Space Consulting"

- Was ist genau Ihre Rolle bei Grün Stadt Zürich?
- Inwiefern spielt die ökologische Qualität bei Ihren Beratungen eine Rolle? Welchen Stellenwert hat ökologische Qualität im Allgemeinen in der Planung und wie hat sich das entwickelt?
- Sehen sie Unterschiede zwischen verschiedenen Entwicklern (Stadt, Genossenschaften, Privaten)?
- Wie schätzen Sie den Unterschied von ökologischer Qualität zwischen Mischnutzungen und reiner Wohnnutzung ein?
- Welche Ansatzpunkte gibt es für die Stadt um auf die ökologische Qualität in Zürich einzuwirken?
- Hatten Sie schon mit *Arealüberbauungen* zu tun? Beraten Sie da speziell?
- Wie schätzen Sie den Wert der Grünräume von *Arealüberbauungen* ein?
- Wie wird die ökologische Qualität in der Beurteilung von Baugesuchen beachtet?
- Fällt Ihnen noch etwas wichtiges zum Thema Ökologische Qualität bei *Arealüberbauungen* ein, das ich bisher nicht angesprochen habe?
- Sind Sie daran interessiert, dass ich Ihnen meine Arbeit nach Abschluss zusende?

Interview with local planner

- Zuerst eine sehr allgemeine Frage: Welchen Stellenwert hat ökologische Qualität im Allgemeinen in der Planung und wie hat sich das entwickelt?
- Haben Sie schon *Arealüberbauungen* geplant? Können Sie Beispiele nennen?
- Ist der Fokus bei *Arealüberbauungen* ein anderer als bei „herkömmlichen" Parzellen? (besonders gute Gestaltung wird wie interpretiert? −¿ für wen besonders gut?)
- Wie wird die Einbettung in die Nachbarschaft geprüft/geplant?
- Welche Rolle spielen Grünflächen bei *Arealüberbauungen* im Vergleich mit anderen Flächen?
- Können Sie einschätzen, wie die Ökologische Qualität in der Evaluation durch die Baukomission beachtet wird?
- Was sind Ihrer Meinung nach die Gründe gegen eine Arealüberbauung? (Kosten?)
- Wie gestaltet sich die Zusammenarbeit/der Austausch mit der Stadt Zürich (Grün Stadt Zürich/AfS)?
- Fällt Ihnen noch etwas wichtiges zum Thema Ökologische Qualität bei *Arealüberbauungen* ein, das ich bisher nicht angesprochen habe?
- Sind Sie daran interessiert, dass ich Ihnen meine Arbeit nach Abschluss zusende?

I Summaries of Expert Interviews

Interview with AfS, Unit for Architecture and Urban Space. The first interview was with an expert from the AfS, Unit for Architecture and Urban Space (AfS, 2022a). The interview started with an explanation of the Building Committee. The Building Committee is responsible for the evaluation of building applications for *Area Developments*. This committee decides if the overall impression of a building project is actually especially well, which is demanded by law. The Building Committee consists of five experts from outside of the city administration and five leading people from the city administration. 8 out of these 10 people have a background in architecture or spatial planning. The remaining two experts are a landscape architect and the director of the GSZ.

For the evaluation of the projects, architecture and urban planning is very important. The especially well design should first of all create an especially well urban space. The concentration is on the cityscape, including quality of life and public space. Since 2012, there are five aspects that need to be looked at during the evaluation: embedding into the urban context, building volumes, physical development and topography, architectural expression, colors and materials. Climate adaptation and climate protection as well as social aspects become more and more important.

With the instrument of *Area Developments*, the city has more power to demand for measures concerning climatic or social aspects than with "normal" building applications. Concerning climate, four important aspects for the evaluation were mentioned in the interview: Sectoral Plan on Heat Reduction of the city of Zurich, "Net-Zero-Strategy" of the city of Zurich, a lot of trees with big crowns, and big areas without built underground. The ecological quality of projects is taken into account by considering the specifications of GSZ about the green share and the degree of sealing. The implementation is examined at the building inspection right after the building phase, but there is no long term monitoring in place. In the discussions of the committee, the term of "green densification" has been mentioned. The spaces surrounding the buildings are a vital part to the compatibility of a dense city. It is more and more important to have wild, complex, multilevel green spaces instead of dull distance green, which does serve neither the ecology nor the living quality.

Four aspects concerning the social space are considered in the evaluation: quality of apartments and buildings (interesting ground-floor uses), quantitative aspects (apartment sizes, rents), temporal aspects (possibility of building in several phases), communicative aspects (include renters in the process). The green spaces of an *Area Development* do not have to be publicly accessible by law, but the especially well overall impression should include a gain for the district. This can be achieved by public spaces, but also through good ground-floor uses or with the design of the buildings themselves. According to the expert, the AfS could still improve their effort to persuade developers of the advantages of such public spaces and uses.

After the complete evaluation, the committee decides if the especially well overall impression is given or not. The decision can also include demands for adjustments of the project. Up until now, these adjustment have mostly been of architectural or spatial planning character. In the future, it is possible that adjustments of open and green spaces are demanded for.

The interviewee was then asked for reasons not to build with the instrument of *Area Developments*. As a first reason the costs were mentioned. It is more costly to build more densly, as more living area is realised. However, the interviewee does not think that this is the main reason. There are high demands on a building project with the instrument of *Area Developments*. Many more requirements need to be met and the Building Committee has to approve the project. Not every developer is willing to adjust the project to these demands to gain the density bonus in return.

Lastly, the further development of the instrument of *Area Developments* was discussed in the interview. There are regular revisions of the BZO, which can be used to improve or alter the instrument. There have been critical voices mentioning “island urbanism”. This means that parcels are developed by themselves without an overall vision for the urban space (see also Hofer (2016)). Such critique needs to be counteracted by a broad vision and regulations that allow the city to intervene in private development projects. A possibility to adjust the instrument of *Area Developments* for the future would be to replace the hard threshold of 6000m^2 by a range. Additionally, the possibility of building in phases could be added to the instrument, where every stage of the building process would have to have an especially well overall impression.

The interview can be summarized as follows: The Building Committee that decides about the especially well overall impression consists mostly of experts for architecture and spatial planning. The focus for the overall impression lies on the urban space, the high quality needs to be advantageous for the people living and spending time in this space. In the last few years, ecological quality became more and more important and several aspects of it are also considered during the building permission procedure.

Interview with AfS, Unit for Area Developments and Planning. The topic of this interview was the overall spatial planning development and the densification of the city of Zurich in connection to *Area Developments*. The Unit for Area Developments and Planning is responsible for the guidance of development projects that go beyond the BZO and are not already clearly legally defined. These are projects like Design Plans or Special Land Use Plans. Additionally, they accompany the revision of the BZO. *Area Developments* are not in their area of competence, as they are clearly legally defined. Therefore, they are directly evaluated by the Building Committee as explained before. The parcels that are accompanied by the expert range in size between about 2000m^2 and 40’000m^2 or even bigger. If the parcels are on the lower end of this spectrum, they are most often situated at a crucial spot in a neighbourhood and many interests need to be considered. When a developer suggests such a project to the city, the city has a big lever as the developer wants to build beyond the BZO and the city can demand for things in return. There are private and public interests on the line and the collaboration between the city and the private developers is needed to find a balance between all these interests. These projects are important for a high quality densification of the city of Zurich. The problem of the city is as follows: Big parts of the city are not dense at all and already the “normal” Zoning Plan offers a big opportunity to densify. In these areas, parcels can be developed through a normal building permission procedure. In this process, the city can only evaluate whether the project confirms with the legal requirements and the quality of the densification can not be judged properly. The AfS is striving to find a way to increase the quality of the building projects in the broad masses and not only for the specific big projects they can accompany. The balance between densification and quality is a big challenge, although quality of densification also leads to living quality and should be seen as an opportunity for private developers and not as a requirement or demand of the city. The *Area Developments* allow the city to ask for more quality and they are therefore certainly an instrument that offers the city a bigger lever than “normal” building permission procedures do. It is an instrument that has an important position in the whole densification discussion. It can serve as an example for all the interests and topics that need to be discussed in high quality densification projects. A further advantage of the *Area Development* is that the higher possible number of storeys reduces the footprint of the building, which again increases the share of green space on the parcel. According to the expert, some developers do not chose to use the instrument of *Area Developments* because the possibilities to densify are already big following only the rules of the Zoning Plan. The requirements of an *Area Development* are quite high and especially for parcels at the threshold of $6000m^2$ it might not be interesting to gain the density bonus for the possibility to only build a few more apartments.

When looking at the ecological quality specifically, this expert does not see a connection between densification and ecological quality per se. Ecological quality and the discussion thereof has its own right to exist. Environmental discussions and problems have increased the importance of the ecological quality in the past years. The requirement for ecologically valuable roof greening has existed in the BZO for a while now. It becomes more and more important that the city can not only demand for green roofs, but also for specific quality requirements for the green spaces. The connection between ecological quality and densification exists because whenever there is a building project nowadays, densification is a primary topic. When a parcel gets densified, the area of the green spaces are most often reduced. Size and quality of green spaces should be discussed separately, as even small green spaces can offer quality.

The threshold of $6000m^2$ of the *Area Development* was also discussed in the interview. This mark has developed with the development of the instrument. In an earlier version of the instrument, the threshold was different for different zones of the Zoning Plan. In residential zones like W2 and W3 the requirement was even higher with a threshold of $8000m^2$. With the revision of the BZO of 1999, the different benchmarks were unified. The medium size was chosen to stay as the only one and this is how the $6000m^2$ became the threshold of today's version of the policy instrument of *Area Developments*.

Lastly, the interviewee shared his personal opinion about the future development of the instrument of *Area Developments*. According to him, the bonus strategy for spatial planning should become obsolete. It would be much more important to already include a basic quality requirement in the Zoning Plan. Quality requirements as well as density requirements should both be included in the BZO and, as mentioned before, looked at as opportunities instead of challenges. The instrument of *Area Developments* should not be abolished, but the whole spatial planning discussion should move in a direction where this instrument is not necessary anymore.

The interview can be summarized as follows: The instrument of *Area Developments* plays an important role for the city's influence on the quality of the densification. Up until now, the legal requirements for ecological quality are not precise enough to ensure high quality densification in the broad mass. When a developer wants to build beyond the BZO, the city has a lever to also demand for higher quality. In the future, basic requirements for ecological quality and densification could be included in the BZO.

Interview with AfS, Unit for Green Space Consulting. This interview had a main focus on how developers are advised by the city concerning ecological quality and how ecological quality of a building application is evaluated and rated (GSZ, 2022).

The Unit for Green Space Consulting is responsible for the evaluation of the green spaces of building applications. It also advises developers on questions about the green spaces. They work closely with the Unit for Nature Protection (translated from "Fachbereich Naturschutz") and the Unit for Green Space Planning (translated from "Fachbereich Freiraumplanung"). During the building permission procedure, the project is checked for its conformity with all the laws and regulations. Concerning green spaces, these regulations concern the share of green space on the parcel, replacement planting of cut trees or embedding in the surroundings. If looking specifically at ecological quality, the legal basis is scarce. Therefore, the experts can only advise on planting native plants for example, this can not be demanded. The ecology got more and more important in the last 10 to 20 years, but especially in the last 3 to 4 years. In this time span, the city of

Zurich compiled several new strategies that deliver a better database for the consultations (see also Stadt Zürich (2020b) or Stadt Zürich (2019b)). Biodiversity and ecology is now remarkably more often mentioned by developers and planners themselves. In some small projects, the awareness about these topics is still small. For these projects it is sometimes difficult to talk about all the important aspects of green spaces in the short time of one consultation. Then, the ecology often comes last, as the aspects with a legal basis are prioritised. When ecology is discussed, the main focus lies on native plants, on unsealed areas and on green facades and roofs.

The expert mentioned that building cooperatives are tendentiously aware about ecological qualities and already propose high quality plans. On the other hand, private investors can often be differentiated by the size of their project. Whereas big projects mostly involve a specific landscape planner, small projects with only an architect pose bigger challenges for high quality green spaces. Not only because of the missing green space expert, but also just because of the sheer size of the parcel. On small parcels it sometimes seems like only the leftover spots can be used for green spaces, whereas open spaces take over a much bigger role on bigger parcels. There is also a noticeable difference between "mixed use" and "residential use" of parcels. On "mixed use" parcels, it is always a fight between green space and development space for parking lots, entrances to parking garages etc. It can also be challenging to combine unsealed areas and wheelchair accessibility, as gravel is not suitable for wheelchairs for example.

Specifically for *Area Developments*, the Unit for Green Space Consulting does have a more possibilities to intervene. The demanded specially well overall impression opens doors for more ecological aspects to be taken into account. It is possible that a building permission is granted, but a plan for the surroundings has to be handed in additionally. This allows for much more detailed evaluation of the green and open spaces. When the surrounding plan is then accepted, the implementation is checked at the building inspection together with all the building aspects. There is room for improvement in this part of the whole process. Sometimes, the people inspecting the builds are not qualified to evaluate the quality of the realised green spaces in comparison to the approved plans. They are mostly educated on architectural structures, look at security issues and legal regulations, while the green spaces are not a priority. The Unit for Green Space Consulting has located this problem and is striving to find a solution to improve the situation. Not only the ecological quality of the space itself is important, but also their functionality in the whole district. *Area Developments* have a special role as a connecting agent because of their size. Due to this, the connection of the parcel with its neighbours and the whole green space network of the area are important factors in the evaluation process as well. In general, the expert rates the ecological value of the green spaces of *Area Developments* as very high, especially because of their connecting function.

The interview can be summarized as follows: The Unit for Green Space Consulting evaluates the green spaces during the building permission procedure. Its primary focus during the evaluation and also for the consultation of developers are the legal rules and regulations that they can build on. Concerning ecological quality, the legal basis is scarce, as the concept of ecological quality is difficult to define. It is a big challenge to satisfy the needs of residents as well as nature in a more and more dense city. A big difficulty in their consultation is often the increasing demand of residents to use the green spaces which stands in contrast to ecologically protected areas. A balance between design, ecology, living quality and function is striven for.

Interview with planner from a local planning office This interview's main focus was to gain another insight into the planning landscape of the city of Zurich from the perspective of a planner (Local Planning Office, 2022). The planner confirmed the already mentioned tendencies towards a higher importance of ecological quality in urban planning. In contrast, ecological quality is much less important in rural planning or in the agglomeration.

The expert himself has already been part of the planning of several *Area Developments*. He was involved in several competition procedures and realised that four to five years ago, ecological quality was no priority at all. Nowadays, it is often a part of the competition program and needs to be integrated by the participants. If the good overall impression of a project is proven through a competition, the ecological criteria are mostly evaluated by an expert. This expert writes a report that supports the judging panel in their decision. The other option to assess the good overall impression is by going through the Building Committee, described in the expert interview with the Unit for Architecture and City Planning (AfS, 2022a). The planner described the procedure from his perspective: the architect and the developer present the project in 10 minutes to the Building Committee, then they have to leave the room whilst the committee is discussing. After a short while, the project team is re-invited into the room and informed about the decision. The consulting period is therefore rather short. Requirements concerning building laws are already checked before that, but it is much more complex to evaluate the quality of the surrounding green spaces. There are no clear criteria to judge the ecological quality in such a short amount of time. Additionally, it might be questionable whether landscape architects are the right people to evaluate ecological quality or if other disciplines will be necessary in urban planning in the future. Historically, the mission of landscape architects was to design, to facilitate usage of areas, to activate plots. This often stands in contrast to ecological quality and the ecosystem services that could be gained from urban green spaces.

Before a project is evaluated in one of the described ways, the expert does not see a big difference between *Area Developments* and other projects. For the evaluation, the special requirements need to be met, but the reward is extremely promising. According to him, the *Area Development* of the city of Zurich is quite "developer-friendly" and is worth investing in. An impressive example is the following: when someone wants to build in a W4 zone under "normal" law (BZO), 4 storeys with a density of 120% can be built; using the instrument of *Area Developments* up to 7 storeys with a density of 160% can be built. Coming from these calculations, he is not convinced that many developers would shy away from the additional requirements. However, other building regulations, such as the distance from the parcel border, could be an obstacle. The bigger a building, the further away it has to be from the parcel border. If the parcel has an unusual geometry, higher buildings might not even be possible, which would lead to not using the instrument of *Area Developments*.

Lastly, he is convinced that the topic of ecological quality and climate adaptation will gain even more attention in the coming years. The new Communal Structure plan, where urban heat islands and city ventilation are increasingly important, is the first step towards being able to require measures concerning climatic topics from private developers. First, the cantonal planning law needs to adapt to enable the communal laws to adjust to the more and more pressing needs of high quality open and green spaces in the city of Zurich.

This interview can be summarised as follows: The perspective of the planner is different to the perspective of the city administration. *Area Developments* offer a big opportunity for developers to gain a density bonus, where the additional requirements are not a big hurdle. To judge ecological quality, new disciplines should be introduced into the evaluation process of all development projects, especially *Area Developments*. The tendencies go in the right direction, but the legal basis to require more measures from privates is still missing.

J Regressiontables

Natural Greening. ANOVA of these three models shows that the Size-Controlled Model should be used. P-value of the Size-controlled Model = 0.00674; p-value of the Full Model = 0.98121 Results of the Kruskal-Wallis-Test: chi-squared = 0.34363, df = 1, p-value = 0.5577.

Table A.5: Regression-Table of all the models for *Natural Greening* with a log-transformation. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model log(Natural greening)	**Multivariate Model log(Natural greening)**	**Size-Controlled Model log(Natural greening)**	**Full Model log(Natural greening)**
intercept	-1.43 . (0.083)	-1.92 . (0.093)	19.61 * (0.011)	19.55 * (0.018)
policy instrument (absent)	-1.16 * (0.033)	-0.85 (0.15)	-3.53 ** (0.0018)	-3.52 ** (0.0060)
building cooperative (Type of Owner 2)		-0.14 (0.82)	-0.57 (0.30)	-0.57 (0.31)
city (Type of Owner 3)		1.28 (0.15)	1.42 . (0.061)	1.42 . (0.068)
mixed use (Type of Use 2)		0.82 (0.37)	0.70 (0.36)	0.71 (0.40)
unbuilt (Land Use before Transformation 2)		-0.85 (0.20)	-1.40 * (0.022)	-1.39 * (0.049)
size			-0.0029 ** (0.0053)	-0.0029 * (0.010)
age				-0.0015 (0.98)
number of observations	26	26	26	26
R^2	0.18	0.35	0.57	0.57
adjusted R^2	0.14	0.18	0.43	0.40
Residual Std. Error	1.30 (df = 24)	1.27 (df=20)	1.055 (df = 19)	1.084 (df =18)
F statistic	5.15 * (df=1;24)	2.11 (df=5;20)	4.19 ** (df=6;19)	3.40 * (df=7;18)

Green Share. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.65419, df = 1, p-value = 0.4186.

Table A.6: Regression-Table of all the models for *Green Share*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Green Share	**Multivariate Model Green Share**	**Size-Controlled Model Green Share**	**Full Model Green Share**
intercept	0.40 *** (1.16e-12)	0.55 *** (6.42e-06)	0.76 (0.24)	0.68 (0.31)
policy instrument (absent)	-0.051 (0.29)	-0.098 . (0.062)	-0.12 (0.20)	-0.10 (0.32)
building cooperative (Type of Owner 2)		-0.025 (0.64)	-0.29 (0.61)	-0.025 (0.66)
city (Type of Owner 3)		-0.11 (0.14)	-0.11 (0.14)	-0.11 (0.17)
mixed use (Type of Use 2)		-0.24 ** (0.0052)	-0.24 ** (0.0060)	-0.22 * (0.020)
unbuilt (Land Use before Transformation 2)		0.059 (0.27)	0.054 (0.34)	0.074 (0.27)
size			-0.000028 (0.75)	-0.0016 (0.86)
age				-0.0033 (0.57)
number of observations	30	30	30	30
R^2	0.039	0.39	0.39	0.40
adjusted R^2	0.0051	0.26	0.23	0.21
Residual Std. Error	0.13 (df = 28)	0.11 (df=24)	0.12 (df = 23)	0.12 (df =22)
F statistic	1.15 (df=1;28)	3.01 ** (df=5;24)	2.43 . (df=6;23)	1.07 . (df=7;22)

Green Share Without Built Underground. ANOVA of the three MLR shows that the smallest one is enough (but p-value for Size-Controlled Model =0.1530). Results of the Kruskall-Wallis Test: chi-squared = 0.8778, df = 1, p-value = 0.3488. The Variable is called “GS (w/o)” in the Table.

Table A.7: Regression-Table of all the models for *Green Share Without Built Underground* (GS w/o) as a log(x/(1-x)-transformation.. Significance codes: ‘***’ for $\alpha < 0.001$, ‘**’ for $\alpha < 0.01$, ’*’ for $\alpha < 0.05$, ‘.’ for $\alpha < 0.1$.

	Bivariate Model log(GS (w/o)/(1-(GS (w/o))))	**Multivariate Model log(GS (w/o)/(1-(GS (w/o))))**	**Size-Controlled Model log(GS (w/o)/(1-(GS (w/o))))**	**Full Model log(GS (w/o)/(1-(GS (w/o))))**
intercept	1.45 (0.24)	0.14 (0.94)	7.002 (0.53)	5.09 (0.65)
policy instrument (absent)	-0.063 (0.94)	0.39 (0.68)	-0.44 (0.79)	0.26 (0.88)
building cooperative (Type of Owner 2)		1.69 (0.11)	1.63 (0.13)	1.89 . (0.092)
city (Type of Owner 3)		0.14 (0.92)	0.14 (0.93)	0.50 (0.74)
mixed use (Type of Use 2)		-0.41 (0.76)	-0.41 (0.77)	0.33 (0.83)
unbuilt (Land Use before Transformation 2)		0.78 (0.41)	0.65 (0.51)	1.39 (0.25)
size			-0.00093 (0.53)	-0.00067 (0.66)
age				-0.11 (0.28)
number of observations	26	26	26	26
R^2	0.00029	0.18	0.20	0.25
adjusted R^2	-0.041	-0.026	-0.058	-0.045
Residual Std. Error	1.9 (df = 24)	1.9 (df=20)	2.0 (df = 19)	1.9 (df =18)
F statistic	0.0069 (df=1;24)	0.87 (df=5;20)	0.77 (df=6;19)	0.85 (df=7;18)

Bush Variable. ANOVA of the three MLR shows that the Size-Controlled Model gives more information than the Multivariate Model; P-value =0.09105. Results of the Kruskall-Wallis Test: chi-squared = 1.4972, df = 1, p-value = 0.2211.

Table A.8: Regression-Table of all the models for the *Bush Variable* with a log-transformation. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model log(Bush Variable)	**Multivariate Model log(Bush Variable)**	**Size-Controlled Model log(Bush Variable)**	**Full Model log(Bush Variable)**
intercept	4.53 *** (4.4e-9)	4.79 *** (1.2e-5)	-3.41 (0.47)	-3.17 (0.52)
policy instrument (absent)	0.16 (0.65)	30.04 (0.92)	1.07 (0.13)	1.01 (0.19)
building cooperative (Type of Owner 2)		-0.045 (0.9124)	0.098 (0.81)	0.087 (0.83)
city (Type of Owner 3)		-0.24 (0.66)	-0.22 (0.68)	-0.24 (0.67)
mixed use (Type of Use 2)		-1.38 * (0.030)	-1.35 * (0.027)	-1.41 * (0.037)
unbuilt (Land Use before Transformation 2)		0.42 (0.30)	0.62 (0.13)	0.56 (0.26)
size			0.0011 . (0.084)	0.0011 (0.11)
age				0.0097 (0.82)
number of observations	30	30	30	30
R^2	0.0074	0.27	0.36	0.36
adjusted R^2	-0.028	0.12	0.19	0.16
Residual Std. Error	0.94 (df = 28)	0.87 (df=24)	0.83 (df = 23)	0.85 (df =22)
F statistic	0.21 (df=1;28)	1.75 (df=5;24)	2.14 (df=6;23)	1.77 (df=7;22)

Number of Trees with Growing Potential. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 1.2082, df = 1, p-value = 0.2717.

Table A.9: Regression-Table of all the models for *Number of Trees with Growing Potential.* Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Growing Potential	**Multivariate Model Growing Potential**	**Size-Controlled Model Growing Potential**	**Full Model Growing Potential**
intercept	3.80 *** (1.7e-7)	5.65 ** (0.0011)	6.69 (0.51)	5.24 (0.62)
policy instrument (absent)	-0.50 (0.48)	-0.89 (0.27)	-1.020 (0.50)	-0.63 (0.70)
building cooperative (Type of Owner 2)		-0.28 (0.74)	-0.30 (0.74)	-0.23 (0.80)
city (Type of Owner 3)		0.036 (0.97)	0.033 (0.98)	0.13 (0.92)
mixed use (Type of Use 2)		-2.60 * (0.044)	-2.61 * (0.048)	-2.24 (0.12)
unbuilt (Land Use before Transformation 2)		-1.61 . (0.060)	-1.63 . (0.072)	-1.26 (0.24)
size			-0.00014 (0.92)	0.000074 (0.96)
age				-0.060 (0.51)
number of observations	30	30	30	30
R^2	0.018	0.25	0.25	0.26
adjusted R^2	-0.017	0.093	0.054	0.031
Residual Std. Error	1.89 (df = 28)	1.78 (df=24)	1.82 (df = 23)	1.84 (df =22)
F statistic	0.52 (df=1;28)	1.59 (df=5;24)	1.28 (df=6;23)	1.13 (df=7;22)

Canopy Cover of Trees. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.95011, df = 1, p-value = 0.3297.

Table A.10: Regression-Table of all the models for *Canopy Cover of Trees*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Canopy Cover of Trees	**Multivariate Model Canopy Cover of Trees**	**Size-Controlled Model Canopy Cover of Trees**	**Full Model Canopy Cover of Trees**
intercept	105.99 *** (0.000056)	122.96 (0.109)	-479.085 (0.32)	-436.27 (0.382)
policy instrument (absent)	19.11 (0.55)	1.89 (0.96)	77.61 (0.28)	66.23 (0.39)
building cooperative (Type of Owner 2)		-6.27 (0.88)	4.25 (0.92)	2.30 (0.96)
city (Type of Owner 3)		-44.17 (0.43)	-42.50 (0.44)	-45.25 (0.42)
mixed use (Type of Use 2)		-94.00 (0.13)	-91.94 (0.13)	-102.67 (0.13)
unbuilt (Land Use before Transformation 2)		31.44 (0.43)	45.87 (0.27)	34.78 (0.49)
size			0.081 (0.21)	0.074 (0.27)
age				1.78 (0.77)
number of observations	30	30	30	30
R^2	0.013	0.16	0.21	0.22
adjusted R^2	-0.022	-0.020	0.0084	-0.028
Residual Std. Error	86.55 (df = 28)	86.44 (df=24)	85.24 (df = 23)	86.8 (df =22)
F statistic	0.37 (df=1;28)	0.89 (df=5;24)	1.041 (df=6;23)	0.89 (df=7;22)

Ground Cover Underneath the Trees (Sum). ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: hi-squared = 0.26882, df = 1, p-value = 0.6041.

Table A.11: Regression-Table of all the models for *Ground Cover Underneath Trees (Sum)* as a log-tranformation. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model log(Sum Ground Cover)	**Multivariate Model log(Sum Ground Cover)**	**Size-Controlled Model log(Sum Ground Cover)**	**Full Model log(Sum Ground Cover)**
intercept	2.41 *** (0.0000033)	3.07 *** (0.000021)	2.075 (0.43)	1.97 (0.62)
policy instrument (absent)	-0.12 (0.65)	-0.36 (0.25)	-0.36 (0.54)	-0.063 (0.92)
building cooperative (Type of Owner 2)		-0.097 (0.76)	-0.097 (0.77)	-0.046 (0.89)
city (Type of Owner 3)		-0.29 (0.50)	-0.29 (0.51)	-0.22 (0.61)
mixed use (Type of Use 2)		-1.13 * (0.024)	-1.13 * (0.027)	-0.85 (0.11)
unbuilt (Land Use before Transformation 2)		-0.42 (0.19)	-0.43 (0.21)	-0.14 (0.72)
size			-0.00000073 (1.00)	0.00016 (0.76)
age				-0.046 (0.18)
number of observations	30	30	30	30
R^2	0.0073	0.24	0.24	0.30
adjusted R^2	-0.028	0.082	0.042	0.078
Residual Std. Error	0.72 (df = 28)	0.68 (df=24)	0.70 (df = 23)	0.68 (df =22)
F statistic	0.21 (df=1;28)	1.52 (df=5;24)	1.21 (df=6;23)	1.35 (df=7;22)

Biodiversity of Trees. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.20826, df = 1, p-value = 0.6481.

Table A.12: Regression-Table of all the models for *Biodiversity of Trees*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Biodiversity	**Multivariate Model Biodiversity**	**Size-Controlled Model Biodiversity**	**Full Model Biodiversity**
intercept	3.47 *** (<2e-16)	3.25 *** (3.41e-5)	-1.23 (0.72)	-1.88 (0.60)
policy instrument (absent)	-0.27 (0.25)	-0.097 (0.73)	0.47 (0.37)	0.64 (0.26)
building cooperative (Type of Owner 2)		0.46 (0.14)	0.53 . (0.088)	0.56 . (0.076)
city (Type of Owner 3)		0.35 (0.39)	0.37 (0.37)	0.41 (0.32)
mixed use (Type of Use 2)		0.20 (0.39)	0.22 (0.62)	0.38 (0.43)
unbuilt (Land Use before Transformation 2)		0.060 (0.84)	0.17 (0.58)	0.33 (0.36)
size			0.00060 (0.20)	0.00070 (0.15)
age				-0.027 (0.39)
number of observations	30	30	30	30
R^2	0.048	0.14	0.20	0.22
adjusted R^2	0.014	-0.044	-0.013	-0.023
Residual Std. Error	0.62 (df = 28)	0.63 (df=24)	0.63 (df = 23)	0.63 (df =22)
F statistic	1.40 (df=1;28)	0.76 (df=5;24)	0.94 (df=6;23)	0.91 (df=7;22)

Table A.13: Regression-Table of all the models for *Biodiversity of Trees* without the Outliers. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Biodiversity w/o outliers	**Multivariate Model Biodiversity w/o outliers**	**Size-Controlled Model Biodiversity w/o outliers**	**Full Model Biodiversity w/o outliers**
intercept	3.50 *** (4.49e-13)	3.16 *** 6.53e-08	1.017 (0.71)	0.96 (0.74)
policy instrument (absent)	-0.031 (0.86)	0.076 (0.72)	0.34 (0.39)	0.35 (0.41)
building cooperative (Type of Owner 2)		0.28 (0.23)	0.32 (0.18)	0.33 (0.19)
city (Type of Owner 3)		0.16 (0.59)	0.18 (0.56)	0.18 (0.57)
mixed use (Type of Use 2)		0.063 (0.85)	0.078 (0.81)	0.091 (0.81)
unbuilt (Land Use before Transformation 2)		0.24 (0.31)	0.29 (0.24)	0.30 (0.29)
size			0.00029 (0.42)	0.00030 (0.44)
age				-0.0021 (0.93)
number of observations	28	28	28	28
R^2	0.0013	0.11	0.14	0.13
adjusted R^2	-0.037	-0.096	-0.11	-0.17
Residual Std. Error	0.45 (df = 26)	0.46 (df=22)	0.47 (df = 21)	0.48 (df =20)
F statistic	0.034 (df=1;26)	0.53 (df=5;22)	0.54 (df=6;21)	0.45 (df=7;20)

SHDI ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.58882, df = 1, p-value = 0.4429.

Table A.14: Regression-Table of all the models for the *SHDI*. Significance codes: '***' for $\alpha <$ 0.001, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model SHDI	**Multivariate Model SHDI**	**Size-Controlled Model SHDI**	**Full Model SHDI**
intercept	0.82*** (1.35e-13)	0.99 *** (2.66e-5)	0.62 (0.57)	0.54 (0.63)
policy instrument (absent)	-0.060 (0.46)	-0.10 (0.23)	-0.056 (0.73)	-0.036 (0.84)
building cooperative (Type of Owner 2)		0.024 (0.78757)	0.031 (0.74)	0.034 (0.72)
city (Type of Owner 3)		-0.047 (0.70)	-0.046 (0.71)	-0.042 (0.75)
mixed use (Type of Use 2)		-0.42 ** (0.0040)	-0.42 ** (0.0048)	-0.40 * (0.014)
unbuilt (Land Use before Transformation 2)		-0.0073 (0.93)	0.0017 (0.099)	0.021 (0.85)
size			0.000050 (0.73)	0.000061 (0.68)
age				-0.0032 (0.75)
number of observations	30	30	30	30
R^2	0.020	0.36	0.37	0.37
adjusted R^2	-0.015	0.23	0.20	0.17
Residual Std. Error	0.22 (df = 28)	0.19 (df=24)	0.19 (df = 23)	0.20 (df =22)
F statistic	0.57 (df=1;28)	2.73 (df=5;24)	2.22 (df=6;23)	1.84 (df=7;22)

Edge Density Index ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 1.8172, df = 1, p-value = 0.1776.

Table A.15: Regression-Table of all the models for the *Edge Density Index*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Edge Density Index	**Multivariate Model Edge Density Index**	**Size-Controlled Model Edge Density Index**	**Full Model Edge Density Index**
intercept	0.14 *** (1.44e-9)	0.14 ** (0.0017)	0.28 (0.30)	0.30 (0.29)
policy instrument (absent)	0.00013 (1.00)	-0.0065 (0.76)	-0.024 (0.55)	-0.029 (0.50)
building cooperative (Type of Owner 2)		0.033 (0.15)	0.030 (0.20)	0.029 (0.22)
city (Type of Owner 3)		-0.018 (0.55)	-0.018 (0.55)	-0.020 (0.54)
mixed use (Type of Use 2)		-0.072 * (0.036)	-0.072 * (0.038)	-0.077 * (0.047)
unbuilt (Land Use before Transformation 2)		0.014 (0.51)	0.011 (0.63)	0.0062 (0.82)
size			-0.000019 (0.60)	-0.000021 (0.57)
age				0.00077 (0.75)
number of observations	30	30	30	30
R^2	0.0000016	0.34	0.34	0.35
adjusted R^2	-0.036	0.20	0.17	0.14
Residual Std. Error	0.053 (df = 28)	0.047 (df=24)	0.048 (df = 23)	0.049 (df =22)
F statistic	0.000044 (df=1;28)	2.43 . (df=5;24)	2.013 (df=6;23)	1.67 (df=7;22)

Number of Patches ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.41333, df = 1, p-value = 0.5203.

Table A.16: Regression-Table of all the models for the *Number of Patches*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Number of Patches	**Multivariate Model Number of Patches**	**Size-Controlled Model Number of Patches**	**Full Model Number of Patches**
intercept	12.86 *** (1.81e-6)	13.50 * (0.017)	29.46 (0.40)	30.75 (0.40)
policy instrument (absent)	0.43 (0.87)	0.21 (0.94)	-1.79 (0.73)	-2.14 (0.71)
building cooperative (Type of Owner 2)		4.40 (0.14)	4.12 (0.18)	4.060 (0.20)
city (Type of Owner 3)		2.63 (0.51)	2.58 (0.52)	2.50 (0.55)
mixed use (Type of Use 2)		-8.074 . (0.069)	-8.13 . (0.0724)	-8.45 . (0.092)
unbuilt (Land Use before Transformation 2)		-6.37 * 0.033)	-6.75 * (0.033)	-7.086 . (0.063)
size			-0.0021 (0.65)	-0.0023 (0.63)
age				0.054 (0.87)
number of observations	30	30	30	30
R^2	0.00096	0.38	0.38	0.39
adjusted R^2	-0.035	0.25	0.22	0.19
Residual Std. Error	7.25 (df = 28)	6.17 (df=24)	6.28 (df = 23)	6.41 (df =22)
F statistic	0.027 (df=1;28)	2.92 * (df=5;24)	2.39 . (df=6;23)	1.97 (df=7;22)

Fitting ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 2.0622, df = 1, p-value = 0.151.

Table A.17: Regression-Table of all the models for *Fitting* (Ordinal Logit Regression). Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Fitting	**Multivariate Model Fitting**	**Size-Controlled Model Fitting**	**Full Model Fitting**
policy instrument (absent)	1.18 (0.15)	1.51 (0.15)	3.00044 *** (4.14e-10)	2.13 *** (0.00030)
building cooperative (Type of Owner 2)		-0.31 (0.78)	-0.27 (0.64)	-0.43 (0.29)
city (Type of Owner 3)		-1.12 (0.51)	-1.18 ** (0.0013)	-1.35 ** (0.0025)
mixed use (Type of Use 2)		0.029 (0.99)	0.076 (0.72)	-0.75 *** (5.43e-7)
unbuilt (Land Use before Transformation 2)		19.098 *** (0.0000000)	19.39 *** (0.0000000)	16.97 *** (0.000000000)
size			0.0015 *** (3.33e-20)	0.00099 (NaN)
age				0.13 (0.22)
number of observations	30	30	30	30
Residual Deviance	53.58	44.084	43.43	42.73
Akaike Information Criterion (AIC)	61.58	60.084	61.43	62.73

Accessible ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.52178, df = 1, p-value = 0.4701.

Table A.18: Regression-Table of all the models for *Accessible* (Ordinal Logit Regression). Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Accessible	**Multivariate Model Accessible**	**Size-Controlled Model Accessible**	**Full Model Accessible**
policy instrument (absent)	-0.50 (0.46)	0.48 (0.56)	0.60 . (0.053)	1.15 ** (0.0043)
building cooperative (Type of Owner 2)		2.053 * (0.033)	2.071 *** (5.43e-14)	2.13 *** (<1e-16)
city (Type of Owner 3)		1.73 (0.16)	1.73 *** (1.11e-9)	1.77 *** (1.24e-8)
mixed use (Type of Use 2)		3.67 * (0.017)	3.67 *** (0.0000000000)	4.15 *** (0.0000000)
unbuilt (Land Use before Transformation 2)		1.36 (0.16)	1.38 *** (2.24e-5)	1.95 *** (<1e-16)
size			0.00013 (0.34)	0.00043 (NaN)
age				-0.076 (0.26)
number of observations	30	30	30	30
Residual Deviance	77.41	68.55	68.54	67.91
AIC	85.41	84.55	86.54	87.91

Artificial Greening ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 3.4916, df = 1, p-value = 0.061683 . .

Table A.19: Regression-Table of all the models for *Artificial Greening*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Artificial Greening	**Multivariate Model Artificial Greening**	**Size-Controlled Model Artificial Greening**	**Full Model Artificial Greening**
intercept	0.22 *** (6.37e-6)	0.27 ** (0.0073)	-0.26 (0.67)	-0.11 (0.86)
policy instrument (absent)	0.025 (0.61)	-0.014 (0.78)	0.053 (0.56)	0.013 (0.89)
building cooperative (Type of Owner 2)		0.023 (0.65)	0.032 (0.54)	0.025 (0.63)
city (Type of Owner 3)		-0.085 (0.23)	-0.084 (0.24)	-0.094 (0.19)
mixed use (Type of Use 2)		-0.25 ** (0.0026)	-0.25 ** (0.0030)	-0.29 ** (0.0018)
unbuilt (Land Use before Transformation 2)		0.038 (0.45)	0.051 (0.34)	0.012 (0.85)
size			0.000071 (0.38)	0.000049 (0.55)
age				0.0063 (0.24)
number of observations	30	30	30	30
R^2	0.0095	0.42	0.44	0.47
adjusted R^2	-0.026	0.30	0.29	0.30
Residual Std. Error	0.13 (df = 28)	0.11 (df=24)	0.11 (df = 23)	0.30 (df =22)
F statistic	0.27 (df=1;28)	3.44 * (df=5;24)	2.97 * (df=6;23)	2.80 * (df=7;22)

Number of Trees ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 1.6004, df = 1, p-value = 0.2058.

Table A.20: Regression-Table of all the models for *Number of Trees* with a log-transformation. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model log(Number of Trees)	**Multivariate Model log(Number of Trees)**	**Size-Controlled Model log(Number of Trees)**	**Full Model log(Number of Trees)**
intercept	1.43 ** (0.0021)	2.11 ** (0.0016)	2.38 (0.55)	1.18 (0.77)
policy instrument (absent)	-0.14 (0.61)	-0.37 (0.24)	-0.40 (0.50)	-0.083 (0.89)
building cooperative (Type of Owner 2)		-0.16 (0.63)	-0.17 (0.63)	-0.11 (0.74)
city (Type of Owner 3)		-0.23 (0.60)	-0.24 (0.61)	-0.16 (0.72)
mixed use (Type of Use 2)		-1.088 * (0.032)	-1.089 * (0.036)	-0.79 (0.14)
unbuilt (Land Use before Transformation 2)		-0.51 (0.12)	-0.52 (0.14)	-0.21 (0.60)
size			-0.000036 (0.95)	0.00014 (0.79)
age				-0.050 (0.16)
number of observations	30	30	30	30
R^2	0.0094	0.23	0.23	0.30
adjusted R^2	-0.026	0.070	0.030	0.076
Residual Std. Error	0.73 (df = 28)	0.70 (df=24)	0.71 (df = 23)	0.69 (df =22)
F statistic	0.28 (df=1;28)	1.43 (df=5;24)	1.15 (df=6;23)	1.34 (df=7;22)

Mean Euclidean Distance ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.83454, df = 1, p-value = 0.361.

Table A.21: Regression-Table of all the models for the *Mean Euclidean Distance* with a log-transformation. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model log(Mean Euclidean Distance)	**Multivariate Model log(Mean Euclidean Distance)**	**Size-Controlled Model log(Mean Euclidean Distance)**	**Full Model log(Mean Euclidean Distance)**
intercept	0.71 . (0.055)	0.38 (0.38)	1.83 (0.51)	1.75 (0.55)
policy instrument (absent)	0.061 (0.79)	0.24 (0.28)	0.052 (0.90)	0.075 (0.87)
building cooperative (Type of Owner 2)		-0.14 (0.55)	-0.16 (0.50)	-0.16 (0.52)
city (Type of Owner 3)		0.43 (0.18)	0.42 (0.19)	0.43 (0.20)
mixed use (Type of Use 2)		1.18 ** (0.0017)	1.18 ** (0.00206)	1.20 ** (0.0043)
unbuilt (Land Use before Transformation 2)		-0.28 (0.21)	-0.32 (0.19)	-0.30 (0.31)
size			-0.00020 (0.59)	-0.00018 (0.63)
age				-0.0036 (0.88)
number of observations	30	30	30	30
R^2	0.0026	0.46	0.47	0.47
adjusted R^2	-0.033	0.35	0.33	0.30
Residual Std. Error	0.61 (df = 28)	0.49 (df=24)	0.49 (df = 23)	0.51 (df =22)
F statistic	0.074 (df=1;28)	4.16 *** (df=5;24)	3.41 * (df=6;23)	2.80 * (df=7;22)

Undesirable Species ANOVA of the three MLR shows that the Size-Controlled Model is the best one.

Table A.22: Regression-Table of all the models for *Undesirable Species* (binomial generalized linear regression). Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Undesirable Species	**Multivariate Model Undesirable Species**	**Size-Controlled Model Undesirable Species**	**Full Model Undesirable Species**
intercept	0.13 (0.80)	-0.15 (0.87)	6.90 (0.49)	7.19 (0.48)
policy instrument (absent)	1.63e-15 (1.000)	0.19 (0.83)	-0.82 (0.62)	-0.92 (0.61)
building cooperative (Type of Owner 2)		-0.22 (0.82)	-0.36 (0.71)	-0.38 (0.70)
city (Type of Owner 3)		0.25 (0.85)	0.23 (0.86)	0.21 (0.87)
mixed use (Type of Use 2)		0.78 (0.59)	0.76 (0.60)	0.67 (0.67)
unbuilt (Land Use before Transformation 2)		0.53 (0.57)	0.34 (0.73)	0.25 (0.83)
size			-0.0012 (0.48)	-0.0011 (0.47)
age				0.015 (0.88)
number of observations	30	30	30	30
Residual Deviance	41.46 (df = 28)	40.51 (df=24)	39.99 (df = 23)	39.97 (df =22)
AIC	45.46	52.51	53.99	55.97

Ground Cover Underneath the Trees (Mean). ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 5.3674, df = 1, p-value = 0.02052 *.

Table A.23: Regression-Table of all the models for *Ground Cover Underneath Trees (Mean)*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Mean Ground Cover	**Multivariate Model Mean Ground Cover**	**Size-Controlled Model Mean Ground Cover**	**Full Model Mean Ground Cover**
intercept	2.73 *** (<2e-16)	2.65 *** (0.8e-9)	2.11 (0.18)	2.32 (0.16)
policy instrument (absent)	0.044 (0.68)	0.026 (0.83)	0.094 (0.41)	0.039 (0.88)
building cooperative (Type of Owner 2)		0.16 (0.23)	0.17 (0.22)	0.16 (0.26)
city (Type of Owner 3)		-0.15 (0.38)	-0.15 (0.40)	-0.16 (0.37)
mixed use (Type of Use 2)		-0.11 (0.57)	-0.11 (0.58)	-0.16 (0.46)
unbuilt (Land Use before Transformation 2)		0.22 . (0.089)	0.24 . (0.090)	0.18 (0.27)
size			0.072 (0.73)	0.000042 (0.85)
age				0.0087 (0.54)
number of observations	30	30	30	30
R^2	0.0063	0.22	0.22	0.24
adjusted R^2	-0.029	0.055	0.020	-0.0069
Residual Std. Error	0.29 (df = 28)	0.27 (df=24)	0.28 (df = 23)	0.28 (df =22)
F statistic	0.18 (df=1;28)	1.34 (df=5;24)	1.10 (df=6;23)	0.97 (df=7;22)

Green Flatroof Share. Results of the Kruskall-Wallis Test: chi-squared = 2.8979, df = 1, p-value = 0.0887 . . There were no regressions of a transformed data set and this variable does not show a normal distribution.

Δ Natural Green. Results of the Kruskall-Wallis Test: chi-squared = 0.22854, df = 1, p-value = 0.6326. There were no regressions of a transformed data set and this variable does not show a normal distribution.

Δ Ground Cover Underneath Trees (Mean). Results of the Kruskall-Wallis Test: chi-squared = 2.1955, df = 1, p-value = 0.1384. There were no regressions of a transformed data set and this variable does not show a normal distribution.

Δ Green Share. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.15527, df = 1, p-value = 0.6936.

Table A.24: Regression-Table of all the models Δ *Green Share*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Δ Green Share	**Multivariate Model Δ Green Share**	**Size-Controlled Model Δ Green Share**	**Full Model Δ Green Share**
intercept	-0.22 ** (0.024)	0.066 (0.57)	0.70 (0.36)	0.64 (0.42)
policy instrument (absent)	0.024 (0.80)	-0.075 (0.22)	-0.16 (0.18)	-0.14 (0.26)
building cooperative (Type of Owner 2)		-0.15 * (0.031)	-0.16 * (0.024)	-0.15 * (0.031)
city (Type of Owner 3)		-0.13 (0.13)	-0.14 (0.13)	-0.13 (0.15)
mixed use (Type of Use 2)		0.17 . (0.079)	0.17 . (0.084)	0.18 . (0.092)
unbuilt (Land Use before Transformation 2)		-0.42 *** (4.81e-7)	-0.44 *** (7.04e-6)	-0.42 *** (2.1e-4)"
size			-0.000085 (0.40)	-0.000076 (0.47)
age				-0.0023 (0.73)
number of observations	30	30	30	30
R^2	0.0023	0.76	0.77	0.77
adjusted R^2	-0.033	0.71	0.71	0.70
Residual Std. Error	0.26 (df = 28)	0.14 (df=24)	0.214 (df = 23)	0.14 (df =22)
F statistic	0.065 (df=1;28)	15.24 *** (df=5;24)	12.68 *** (df=6;23)	10.47 *** (df=7;22)

Δ Artificial Greening. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.00043, df = 1, p-value = 0.98.

Table A.25: Regression-Table of all the models for Δ *Artificial Greening*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Δ Artificial Greening	**Multivariate Model Δ Artificial Greening**	**Size-Controlled Model Δ Artificial Greening**	**Full Model Δ Artificial Greening**
intercept	-0.18 ** (0.0049)	-0.15 (0.42)	-0.16 (0.90)	-0.078 (0.95)
policy instrument (absent)	0.16 . (0.066)	0.099 (0.32)	0.099 (0.59)	0.078 (0.70)
building cooperative (Type of Owner 2)		-0.11 (0.32)	-0.11 (0.34)	-0.11 (0.33)
city (Type of Owner 3)		-0.081 (0.57)	-0.081 (0.58)	-0.086 (0.56)
mixed use (Type of Use 2)		0.0068 (0.97)	0.0068 (0.97)	-0.013 (0.94)
unbuilt (Land Use before Transformation 2)		-0.18 . (0.081)	-0.18 (0.10)	-0.20 (0.13)
size			0.00000044 (1.00)	-0.000011 (0.95)
age				0.0033 (0.77)
number of observations	30	30	30	30
R^2	0.12	0.27	0.27	0.27
adjusted R^2	0.084	0.12	0.077	0.039
Residual Std. Error	0.23 (df = 28)	0.22 (df=24)	0.23 (df = 23)	0.23 (df =22)
F statistic	3.66 . (df=1;28)	1.76 (df=5;24)	1.40 (df=6;23)	1.17 (df=7;22)

Δ Number of Trees. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.80, df = 1, p-value = 0.37.

Table A.26: Regression-Table of all the models for Δ *Number of Trees*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Δ Number of Trees	**Multivariate Model Δ Number of Trees**	**Size-Controlled Model Δ Number of Trees**	**Full Model Δ Number of Trees**
intercept	3.33 *** (0.00016)	7.67 ** (0.0065)	5.40 (0.75)	3.53 (0.84)
policy instrument (absent)	-1.22 (0.27)	-2.36 . (0.089)	-2.071 (0.42)	-1.57 (0.57)
building cooperative (Type of Owner 2)		-1.57 (0.28)	-1.53 (0.31)	-1.45 (0.35)
city (Type of Owner 3)		-2.087 (0.29)	-2.080 (0.30)	-1.96 (0.34)
mixed use (Type of Use 2)		-2.087 (0.34)	-2.020 (0.35)	-1.55 (0.52)
unbuilt (Land Use before Transformation 2)		-1.49 (0.29)	-1.44 (0.34)	-0.95 (0.60)
size			0.00030 (0.89)	0.00058 (0.81)
age				-0.078 (0.62)
number of observations	30	30	30	30
R^2	0.044	0.15	0.15	0.16
adjusted R^2	0.0095	-0.027	-0.071	-0.11
Residual Std. Error	2.96 (df = 28)	3.016 (df=24)	3.079 (df = 23)	3.13 (df =22)
F statistic	1.28 (df=1;28)	0.85 (df=5;24)	0.68 (df=6;23)	0.60 (df=7;22)

Δ Canopy Cover of Trees. ANOVA of the three MLR shows that the Size-Controlled Model is the best one. Results of the Kruskall-Wallis Test: chi-squared = 0.23, df = 1, p-value = 0.63.

Table A.27: Regression-Table of all the models for Δ *Canopy Cover of Trees*. Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Δ Canopy Cover of Trees	**Multivariate Model Δ Canopy Cover of Trees**	**Size-Controlled Model Δ Canopy Cover of Trees**	**Full Model Δ Canopy Cover of Trees**
intercept	18.53 (0.47)	47.38 (0.58)	-1014 . (0.059)	-974.69 . (0.081)
policy instrument (absent)	8.94 (0.80)	-12.27 (0.78)	121.2 (0.12)	110.82 (0.19)
building cooperative (Type of Owner 2)		-17.93 (0.70)	0.60 (0.99)	-1.17 (0.98)
city (Type of Owner 3)		-76.44 (0.24)	-73.51 (0.22)	-76.0032 (0.22)
mixed use (Type of Use 2)		-36.60 (0.60)	-32.97 (0.61)	-42.72 (0.55)
unbuilt (Land Use before Transformation 2)		59.28 (0.20)	84.72 . (0.067)	74.65 (0.18)
size			0.14 * (0.047)	0.14 . (0.067)
age				1.62 (0.73)
number of observations	30	30	30	30
R^2	0.0022	0.12	0.26	0.26
adjusted R^2	-0.033	-0.068	0.066	0.028
Residual Std. Error	97.49 (df = 28)	0.63 (df=24)	1.34 (df = 23)	1.12 (df =22)
F statistic	0.063 (df=1;28)	0.63 (df=5;24)	1.34 (df=6;23)	1.12 (df=7;22)

Δ Number of Trees with Growing Potential. ANOVA of the three MLR shows that the smallest one is enough. Results of the Kruskall-Wallis Test: chi-squared = 0.52688, df = 1, p-value = 0.4679.

Table A.28: Regression-Table of all the models for Δ *Number of Trees with Growing Potential.* Significance codes: '***' for $\alpha < 0.001$, '**' for $\alpha < 0.01$, '*' for $\alpha < 0.05$, '.' for $\alpha < 0.1$.

	Bivariate Model Δ Number of Trees with Growing Potential	**Multivariate Model Δ Number of Trees with Growing Potential**	**Size-Controlled Model Δ Number of Trees with Growing Potential**	**Full Model Δ Number of Trees with Growing Potential**
intercept	2.25 *** (0.00014)	4.25 * (0.023)	-8.78 (0.44)	-9.64 (0.42)
policy instrument (absent)	-0.44 (0.55)	-1.025 (0.27)	0.61 (0.71)	0.84 (0.65)
building cooperative (Type of Owner 2)		-0.51 (0.60)	-0.28 (0.78)	-0.24 (0.81)
city (Type of Owner 3)		-1.053 (0.43)	-1.017 (0.44)	-0.96 (0.47)
mixed use (Type of Use 2)		-1.49 (0.30)	-1.45 (0.31)	-1.23 (0.44)
unbuilt (Land Use before Transformation 2)		-0.78 (0.41)	-0.47 (0.63)	-0.24 (0.84)
size			0.0018 (0.25)	0.0019 (0.24)
age				-0.036 (0.73)
number of observations	30	30	30	30
R^2	0.013	0.089	0.14	0.15
adjusted R^2	-0.022	-0.10	-0.083	-0.13
Residual Std. Error	1.97 (df = 28)	2.047 (df=24)	2.031 (df = 23)	2.071 (df =22)
F statistic	0.37 (df=1;28)	0.47 (df=5;24)	0.63 (df=6;23)	0.54 (df=7;22)

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