



Socio-Spatial (In)Equality of Access to Urban Green Space: A Case in Beijing

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Socio-Spatial (In)Equality of Access to Urban Green Space: A Case in Beijing

A dissertation presented

By

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“Bachelor of Engineering in Landscape Architecture, Beijing Forestry University”

“Master of Engineering in Urban Planning, Beijing Forestry University”

“Master in Design Studies, Harvard University”

To

Harvard University Graduate School of Design

in partial fulfillment of the requirements

for the degree of

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Dissertation Title: Socio-Spatial (In)Equality of Access to Urban Green Space: A Case in Beijing

Abstract

Green space, as an important component of urban system, deliver multiple benefits to urban residents. From an ecosystem service perspective, these benefits include: provisioning services, regulating services, supporting services, and cultural services. Unfortunately, studies have confirmed that green spaces are not equally accessible among different socio-economic groups in urban areas. Such unequal socio-spatial pattern of accessing green spaces lead to many other undesirable outcomes including social segregation, dislocation, and gentrification, and finally causes exclusive urban development benefiting a smaller portion of population. It is in this context that my dissertation explores how urban green spaces and their varying benefits accessible for different social groups intertwining with geo-morphological, historical, socio-economic, and political factors in complex urban circumstances by using Beijing as a case.

Relying on multiple open source data sets and spatial statistical analyses, this dissertation addresses three major questions: 1) How are urban green spaces distributed among socio-economic groups (a cross sectional study in 2017)? 2) Are urban green spaces more often provided to advantaged socio-economic groups (a longitudinal study 2000-2010)? And 3) Does adding new green space gentrify the neighboring communities in Beijing, thus resulting in the dislocation of marginalized groups? In the cross-sectional study, the results indicate the public green spaces tend to serve marginalized groups more, while advantaged socio-economic groups are better served by internal vegetations

in the gated communities in which they live. The results of longitudinal study did not identify significant associations between the changes of green spaces and the socio-economic statuses in Township (census tract unit), indicating afforestation process exerts little discrimination against marginalized groups. Finally, adding new green spaces can trigger gentrification by increasing the housing prices in the neighboring communities, although the capitalization scale of green spaces depends based on a variety of features. Distance to a property, area, vegetation quality, presence of water features, and types of green space all play different roles in affecting the housing price thus having divergent capacities of triggering gentrification.

Key words

Urban Green Space, Social Equality, Ecosystem Services, Accessibility, Gentrification, Urban Planning, Beijing

Table of Content

Socio-Spatial (In)Equality of Access to Urban Green Space: A Case in Beijing.....	i
1. Introduction.....	1
1.1. Background.....	1
1.2. Literature Review.....	4
1.3. Structure of the Dissertation	15
2. Urban Green Space in Beijing	17
2.1. A Brief History: Urban Green Space Development in Beijing.....	18
2.2. Processes and Players of Urban Greening in Beijing	32
2.3. Recent Status and New Challenges.....	35
3. Summary of Research Methods and Data.....	43
3.1. Defining Urban Green Spaces	43
3.2. Identifying Marginalized Socio-economic Groups.....	46
3.3. Measuring Benefits of Urban Green Space	49
3.4. Analytical Methods.....	54
3.5. Data Sources and Processing	59
3.6. Summary of Data and Methods Used in This Dissertation.....	63
4. The Distributional Pattern.....	64
4.1. Introduction.....	65
4.2. Data and Methods	66
4.3. Results.....	84
4.4. Discussions	98
4.5. Summary of Section 4.....	112

5.	The Allocating Process	113
5.1.	Introduction.....	114
5.2.	Data and Methods	116
5.3.	Results.....	132
5.4.	Discussions	148
5.5.	Summary of Section 5.....	153
6.	The “Green Paradox”	154
6.1.	Introduction.....	155
6.2.	Data and Method.....	157
6.3.	Results.....	173
6.4.	Discussions	182
6.5.	Summary of Section 6.....	187
7.	Conclusion	188
7.1.	Summary of Findings.....	188
7.2.	Application in Urban Green Space Planning and Design.....	190
7.3.	Limitations and Future Studies	192
8.	Appendix.....	194
8.1.	Diagnostic of OLS for Spatial Autocorrelation in 4.3.1	194
8.2.	Report of Geographically Weighted Regression in 4.3.2	195
8.3.	Adjustment of Administrative Divisions in Beijing	196
8.4.	Land Use Classification Accuracy Assessment.....	198
8.5.	Diagnostic of for Spatial Autocorrelation in 5.3.2.....	199
8.6.	Graphical Analysis for Regression Results in 6.4.1	200

8.7.	Falsification Test for Regression Results in 6.4.1	201
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Cambridge, MA

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For my family: Meishu Piao, Chaomei Wu, and Zhenzi Jin

List of Figures

Figure 2-1 Beijing old city and its outskirts in 1926. (Great Britain War Office, Great Britain Ordnance Survey, & United States Army Map Service, 1927).....	19
Figure 2-2 Wanshou Hill, Kunming Lake, and Nanhu Island at Yihe Yuan and fields to the west. (Morrison, 1933).....	19
Figure 2-3 Hall of Prayer for Harvests in Tian Tan. (Warner, 1923).....	19
Figure 2-4 The Forbidden City and the periphery areas of Beijing. (21st (Photographic Reconnaissance) Squadron (USAAF), 1945).....	20
Figure 2-5 Street trees in Dong Zhi Men Area. (Beijing Local Chronicles Compilation Committee, 2000).....	21
Figure 2-6 Draft of Beijing Master Plan 1954 (Beijing City Planning Commission, 1953).....	22
Figure 2-7 Beijing Master Plan 1958 (Beijing City Planning Commission, 1958).....	22
Figure 2-8 Beijing Master Plan 1973 (Beijing City Planning Commission, 1973).....	23
Figure 2-9 Parks trees were replaced by crops for production, Long Tan Hu Park in 1955 (Beijing Local Chronicles Compilation Committee, 2000).....	23
Figure 2-10 Beijing Master Plan 1982 (Beijing Municipal Commission of Urban Planning, 1982).....	25
Figure 2-11 Beijing Master Plan 1992 (Beijing Municipal Commission of Urban Planning, 1992).....	26
Figure 2-12 Olympic Forest Park for both hosting the 2008 Game and serving local residents. (Tsinghua Urban Planning and Design Institute, 2015).....	27

Figure 2-13 Central City Land Use Planning of Beijing Master Plan 2004-2020 (Beijing Municipal Institute of City Planning and Design, 2007)	28
Figure 2-14 The conceptual structure of urban green spaces of Beijing Master Plan 2004-2020 (Beijing Municipal Institute of City Planning and Design, 2007)	30
Figure 2-15 The urban green spaces network of Beijing Master Plan 2016-2035 (Beijing Municipal Bureau of Land and Resources, 2017)	31
Figure 2-16 The processes and players of urban greening in Beijing.....	34
Figure 2-17 Satellite image of Beijing. (Gaode, 2018).	35
Figure 2-18 The total area of park green spaces in Beijing 1978-2015 (Capital Greening Office, 2017).....	36
Figure 2-19 The area of park per capita 1978-2015 (Capital Greening Office, 2017).	36
Figure 2-20 The urban green space coverage ratio in Beijing 1978-2015 (Capital Greening Office, 2017)	37
Figure 4-1 The study area and the townships in Beijing. Author drawn based on administrative map of Beijing 2014.....	66
Figure 4-2 Topography and administrative border. Author drawn based on NASA 2019 and administrative map of Beijing 2014.....	67
Figure 4-3 Inner green space and other amenities in a gated community.	68
Figure 4-4 Built year of residential communities in Beijing (sample used in this study). Author drawn based on Gaode Map 2017 and Lianjia 2018.	69
Figure 4-5 Distribution of residential communities in Beijing (sample used in this study). Author drawn based on Gaode Map 2017.	70
Figure 4-6 Average housing transaction price per sqm.	72

Figure 4-7 Average housing unit area in sqm.....	72
Figure 4-8 Population with bachelor or higher degree.	73
Figure 4-9 Population with local hukou.....	73
Figure 4-10 Unemployment rate.....	74
Figure 4-11 Population who live in an owned property	74
Figure 4-12 The quality and distribution of public green spaces. Author drawn based on NASA 2018, ESA 2018, and Capital Greening Office 2017.....	77
Figure 4-13 Conceptual diagram for measuring access to public green spaces (left) and internal vegetation coverage (right).....	77
Figure 4-14 GWR results mapping approach. Author drawn based on Tooke et al.	83
Figure 4-15 Rank of Socioeconomic status (high shaded as green; low shaded as red). .	86
Figure 4-16 Anselin Local Moran’s I index.	86
Figure 4-17 Accessibility to public green spaces at residential community level.....	87
Figure 4-18 Vegetation coverage ratio at residential community level.....	87
Figure 4-19 Local coefficients between access to parks and socio-economic status	93
Figure 4-20 Local R-square of coefficients between access to parks and socio-economic status	93
Figure 4-21 Low social status-High park access(orange) VS High social status-Low park access(blue).....	94
Figure 4-22 Low social status-Low park access(red) VS High social status-High park access(green).....	94
Figure 4-23 Local coefficients between vegetation coverage and socio-economic status	96

Figure 4-24 Local R-square of coefficients between vegetation coverage and socio-economic status	96
Figure 4-25 Low social status-High vegetation coverage(yellow) VS High social status-Low vegetation coverage (blue).....	97
Figure 4-26 Low social status-Low vegetation coverage(red) VS High social status-High vegetation coverage (green).....	97
Figure 4-27 Geographical Bases Set the Tone.....	100
Figure 4-28 Historical Heritages Frame the Green Network.....	103
Figure 4-29 The Influence of Urban Master Planning.....	106
Figure 4-30 Belated Efforts of Urban Afforestation and Environmental Concerns.	109
Figure 4-31 Stress of Financial Burden and Real Estate Development.....	111
Figure 5-1 Six districts and adjusted subdistricts.	117
Figure 5-2 Employment rate in 2000	118
Figure 5-3 Employment rate in 2010	118
Figure 5-4 Percentage of local Hu Kou residents in 2000	119
Figure 5-5 Percentage of local Hu Kou residents in 2010	119
Figure 5-6 Percentage of people with bachelor or higher degree in 2000	120
Figure 5-7 Percentage of people with bachelor or higher degree in 2010	120
Figure 5-8 Housing area per capita (sqm) in 2000	121
Figure 5-9 Housing area per capita (sqm) in 2010	121
Figure 5-10 Conceptual diagram of measuring access to parks (left) and urban vegetation (right).	123
Figure 5-11 Public green spaces in 2000	124

Figure 5-12 Public green spaces in 2010	124
Figure 5-13 Accessibility to public green spaces in 2000	125
Figure 5-14 Accessibility to public green spaces in 2010	125
Figure 5-15 Urban vegetation coverage in 2000.....	126
Figure 5-16 Urban vegetation coverage in 2010.....	126
Figure 5-17 Area of vegetation per capita in 2000	127
Figure 5-18 Area of vegetation per capita in 2010	127
Figure 5-19 The change of access to park green spaces during 2000 and 2010.	133
Figure 5-20 The change of urban vegetation coverage during 2000 and 2010.	134
Figure 5-21 Local relationships between employment rate change and park access change.	138
Figure 5-22 Local relationships between employment rate change and vegetation coverage change.....	139
Figure 5-23 Local relationships between education level change and park access change.	140
Figure 5-24 Local relationships between education level change and vegetation coverage change.	142
Figure 5-25 Local relationships between local hukou population change and park access change.	143
Figure 5-26 Local relationships between local Hu Kou population change and vegetation coverage change.....	144
Figure 5-27 Local relationships between changes of living area per capita and park access.	146

Figure 5-28 Local relationships between changes of living area per capita and vegetation coverage.....	147
Figure 6-1 Mechanism of green space related gentrification in Beijing.....	158
Figure 6-2 Examples of four types of green space in this study: Comprehensive Park (top-left); Natural Park (top-right); Theme Park (bottom-left); Historical Park (bottom-right). Author drawn based on Google Earth, Gaode Map, and Capital Greening Office, 2018.	164
Figure 6-3 Type and distribution of park green spaces. Author drawn based on Google Earth, Gaode Map, and Capital Greening Office, 2018.....	164
Figure 6-4 Housing price and spatial distribution. Author drawn based on Lianjia, 2018.	167
Figure 6-5 Housing transaction year. Author drawn based on Lianjia, 2018.	168
Figure 6-6 Housing transaction used in the study and the newly built green space in 2011-2018. Author drawn based on Lianjia, Google Earth, Gaode Map, and Capital Greening Office, 2018.	169
Figure 8-1 Residual plot of log price regression before and after green space built time	200

1. Introduction

1.1. Background

Green space, as an important component of urban system, deliver multiple benefits to urban residents. From an ecosystems services perspective, these benefits include: provisioning services, regulating services, habitat or supporting services, and, more generally, cultural services (Berghöfer et al., 2011). Socio-economic, cultural, historical, and political agencies are also involved in the delivery of benefits from green spaces in urban areas. It is in this context that my dissertation explores how these “services” for city residents intertwine with morphological and socio-economic factors in complex urban environments by using Beijing as a case.

Chinese municipal governments have been investing tremendously in urban greening projects to mitigate environmental degradation since the early 21st century (J. Zhao et al., 2013). As a result, the overall volume and quality of urban green spaces has improved massively in China. However, decision-makers and urban planners focus more on the geo-spatial patterns and ecological benefits of green space, often overlooking socioeconomic dimensions which might lead to undesirable outcomes such as environmental inequality, gentrification, dislocation, and segregation. Additionally, the insufficient regulations enforcement, limited financing system, and oversimplified planning techniques inhibit the delivery of an efficient pattern of urban green spaces that are equally accessible among different social groups.

Understanding the spatial pattern of how different socio-economic groups access urban green space is the first step to addressing inequality issue. Existing studies construe urban green space in an overly broadly manner. A majority of the studies define urban

green space as a uniform amenity focusing individual feature such as size. Green spaces with different sizes, shapes, types, features, and quality of maintenance exert varying levels of benefit and service to users (Forman, 2014; L. Xu, You, Li, & Yu, 2016). The contextual historical, geo-morphological, and socio-economic dimensions might also influence the distributional patterns. Further studies therefore need to consider the specific types of features of green spaces in different urban contexts to avoid biased conclusions for planners' and decision makers' reference.

The second step is to discern the synergy of varying benefits of green spaces throughout time as well as the driving factors of socio-spatial inequality (if observed) in accessing urban green spaces. A longitudinal study is needed by comparing the changes of accessing urban green spaces and socio-economic statuses as well as potential attributable factors involved in the process. Additionally, the trade-off effect is also to be examined. This is because the varying benefits of urban green spaces exist in reality—the loss of certain benefit of one green space might be supplemented by another.

Lastly, green spaces are known to trigger gentrification by stimulating neighboring housing sales prices or attracting high-end real estate development at vicinity (Crompton, 2005; Kong, Yin, & Nakagoshi, 2007; Wolch, Byrne, & Newell, 2014). The gentrified neighborhood and subsequent increase in wealth residents attracts better amenities, and in turn, this attracts more advantaged groups in a kind of snowball effect (Zheng & Kahn, 2013). Without proper subsidy policies and regulations, the green spaces that should be accessible to most of the residents in a given area wind up serving only a limited group of wealthy people because of this “green gentrification”. Thus, to secure the equal socio-spatial pattern of green spaces created, it is necessary to discern if adding

green spaces can generate undesirable outcomes including gentrification by dislocating marginalized groups.

The reasons for selecting Beijing as a representative case study are multifold. First, Beijing, as the capital city of China, is a pioneer in terms of investment in urban greening. The government invested in various urban afforestation projects in the past two decades to mitigate environmental degradation and improve the life quality of its residents. The development level of green spaces is among the top in the country¹ and is considered to be a “model” from which others should learn. Second, the city is rich with numerous historical heritage sites, some of which are well-known royal gardens and palaces supplementing as urban green spaces nowadays. Similarly, many other cities in China are abundant with historical sites and have been taken advantage of by today’s urban planners in order to frame the network of green spaces of a city. Third, Beijing is confronting serious environmental challenges such as air pollution, water and soil loss, urban sprawl, etc. So, the planting of more trees is one of the key approaches for addressing these issues.

¹ The green space coverage ratio in urban built up area of Beijing is 47.68% ranked 10th among 300 more prefecture-level cities in year 2010 according to the China Yearbook 2010. Beijing is also the first city given by the “National Garden City” accolade—the only national level standard about urban green space development.

1.2. Literature Review

Green spaces deliver multiple benefits to urban residents. From an ecosystems services perspective, these benefits include: provisioning services, regulating services, habitat or supporting services, and, more generally, cultural services (Berghöfer et al., 2011). Provisioning services include material outputs from ecosystems such as food, water, medicinal plants, as well as a whole host of other resources. Regulating services perform functions that maintain air and soil qualities, as well as flood and storm-water levels, and even aid in disease control. Habitat and supporting services provide living spaces for organisms. Finally, cultural services provide benefits to non-material, socio-ecological, and the health of individuals (e.g. psychological and cognitive benefits), all of which people obtain from contact with their environments by means of diverse phenomena such as recreation, aesthetics, spirituality, or tourism (Berghöfer et al., 2011).

Ecosystem services provided by green spaces vary according to characteristics such as function, size, vegetation, design, maintenance, and spatial configuration, as well as the various contexts of urban geographical environments including topology, periphery land use, building density, and urban design features. Moreover, there are also socio-economic and political factors associated with the spatial variances of different benefits of green spaces. All these factors intercorrelate with each other to shape the socio-spatial (in)equality of urban green spaces. This subsection reviews related literatures on the issue starting with introduction to the types of benefits of green space in urban circumstances and further detailing the attributable factors involved in delivering these diverse benefits.

1.2.1. Geo-Morphological Dimensions: Features and Context

The delivery of ecosystem services from green spaces to people is about how well these services can be accessed or received by the potential users. Ecosystem services are not only determined by features of green spaces including size, vegetation types, design, maintenance, and interrelated processes of these features, but is also influenced by various contextual aspects of urban-geographical environments including topology, peripheral land use, building density, and urban design.

1.2.1.1. Features of Urban Green Space

The features of green space include the size, shape, vegetation diversity and density, amenities, design, and maintenance. These features are useful when evaluating the static value of green spaces, and are often more commonly adopted to measure non-spatial explicit services such as carbon sequestration (Kremer, Hamstead, & McPhearson, 2016), stormwater absorption (Kremer et al., 2016; L. Yang, Zhang, Li, & Wu, 2015; B. Zhang, Xie, Li, & Wang, 2015), air pollution removal (Graça et al., 2018), output of raw materials from vegetation (D. Haase et al., 2014), etc..

A majority of these studies calculate multiple benefits or ecosystem services of green spaces by integrating varying features and processes related to the benefits. This is because the specific benefits of an urban green space are often correlated with many other attributes. For example, the stormwater management capacity is determined by ground vegetation types, soil condition, size and slope, intensity and amount of precipitation, and other factors. Through land use, remote sensing, and experimental data, Kremer et al. examined the spatial distribution of five ecosystem services, including storm water absorption, carbon storage, air pollution removal, local climate regulation, and recreation in order to create a multiple ecosystem services evaluation of all green infrastructure in

NYC (Kremer et al., 2016). Based on remote-sensing image interpretation and practical investigations in Yixing (China), Yang et al. evaluated the water regulation and purification functions performed by urban green spaces using the modified Soil Conservation Service model in conjunction with relevant experimental data determining the capacity of runoff retainment (L. Yang et al., 2015).

1.2.1.2. Configuration of Urban Green Spaces

Furthermore, a series of green space patches with different spatial attributes (richness, accessibility, shape/configuration, and distributional characteristics) that may have different ecological functions should therefore contain varied amounts of ecosystem service values and benefits (Forman, 2014). Landscape metrics describing the patch aggregation, density, and diversity are commonly used to measure the performances of urban green spaces that have different spatial configurations and distributional patterns (B. Zhang, Li, Xie, & Shi, 2017).

Such measurement can be powerful in describing the static or changing spatial patterns of urban green spaces, but its capacity to detect the overall values or delivery of different benefits to potential users is limited. Integrating the landscape metrics with other measuring approaches can better reveal the ecosystem benefits or services from green spaces with different spatial and configurational features. Common cases interpret the values or performances of landscape patterns of green spaces by willingness-to-pay approaches such as hedonic pricing model (Kong et al., 2007; L. Xu et al., 2016). Using Beijing as a case, Xu et al. found certain spatial characteristics of urban green spaces are more desirable among a city's residents by using a hedonic pricing mode (L. Xu et al., 2016). Similarly, a study in Jinan (China) found that aggregation level of green spaces

positively influences housing prices and thus showed that aggregation is more favorable among urban residents (Kong et al., 2007). Another strand of literatures links the landscape metrics with their environmental regulating outcomes such as air pollution mitigation (J. Wu, Xie, Li, & Li, 2015).

1.2.1.3. Urban Form

Studies have confirmed urban form measured by morphological factors including building density, road density, topography, and elevation can all be useful identifiers of quantity and quality of urban green spaces that further relate with multiple ecosystem services. Using data from selected areas in five UK cities, Tratalos studied the relationships between urban form and the following measures of ecosystem services of green spaces (Tratalos, Fuller, Warren, Davies, & Gaston, 2007). The varying relationships between coverage of types of green spaces and urban density are confirmed to be statistically significant, while the magnitudes and directions of associations between the ecosystem services—such as habitat size, run-off control, and biodiversity—of green spaces and urban density are widely different (Tratalos et al., 2007). Davies et al. use Sheffield, U.K. as a case study of city-wide relationships between urban green space extent, quality (in terms of vegetation cover, tree-cover, etc.), and gradients in urban form and topography (Davies et al., 2008). The study confirms that elevation, slope, housing density, and type are effective predictors of both the quality and quantity of urban green spaces (Davies et al., 2008). By comparing 105 cities in China, Wang and Yuan found increasing urban density measured by the population per square kilometer of built urban area reduced per capita park and green spaces (R. Wang & Yuan, 2017). In Lin et al.'s study, the cooling effect is not only assessed by ground temperature within green spaces but includes the effects on areas around a park (Lin, Yu, Chang, Wu, & Zhang, 2015).

The result shows the cooling extension of a park still increases with its size, though this is affected by the conditions of its surrounding environment such as building density (Lin et al., 2015).

Additionally, urban design features such as street networks and integrity, public transportation, land use types, and urban-rural gradients influence the provision of varying benefits provided by green spaces. Street network and integrity along with public transportation can determine spatial variances in accessing urban green spaces for obtaining recreational and environment-regulating benefits (Fan, Xu, Yue, & Chen, 2017; Pham, Apparicio, Landry, & Lewnard, 2017). To quantify the recreation and biodiversity benefits of green spaces, Soga et al. compares how two types of urban land use development types—dispersed and compact developments—in Tokyo are visited by residents, and the result show that green spaces in dispersed development have more recreational value but a lower capacity for maintaining biodiversity (Soga et al., 2015). Through introducing new measuring tools, Stähle measures how urban design affects green space accessibility; the author concludes that some urban designs provide increased access to green spaces and dense land use might not necessarily conflict with providing more green spaces with better designed spatial configuration (Stähle, 2010). A study using Beijing, Guangzhou, and Hangzhou as cases confirmed that cultural and regulating services of green spaces vary along the urban-rural gradient measured by building density (Chang et al., 2017).

1.2.2. Socio-economic Dimension: People and Preferences

Apart from geo-morphological dimensions, socio-economic, cultural, and political agencies are also involved in affecting the delivery of benefits from green spaces in urban

settings, which has attracted the attention of numerous scholars in recent decades. Apart from mere concentration on supply and demand of urban green space, recent studies start to link the benefits of green spaces with population subdivisions (mostly) based on their socio-economic statuses and further connect the diverging perceptions and preferences that are associated with the demographical and socio-economic backgrounds.

1.2.2.1. Supply and Demand

The supply and demand approach is used to gauge the service level of public amenities including urban green spaces and is thus helpful in aiding urban planning practices. By considering demographic attributes, a case study in Dalian, China shows uneven distribution of the city dwellers' access to urban green spaces (J. Yang et al., 2015). Hong et al. integrate the functions of green space systems with human needs and assess the benefits of landscape aesthetics, the functions of disaster prevention and mitigation, and accessibility to park greenbelts; the results yield a high service level of parks in Shenzhen (Hong & Guo, 2017). However, the approach is criticized for oversimplifying the complicated socio-spatial patterns of cities by excluding factors such as the attributes of parks, transportation modes, socio-economic status, and psychological factors of users (Lee & Hong, 2013; Xing, Liu, Liu, Wei, & Mao, 2018).

1.2.2.2. Socio-economic Statuses

Next, spatial distribution and access to urban green spaces varies among groups based on a wide variety of socio-economic factors, from racial and ethnic factors (Dai, 2011; Matthew McConnachie & Shackleton, 2010; Talen, 2013; Wolch et al., 2014), to income and economics (Tooke, Klinkenber, & Coops, 2010), education levels, migration status, and even age (Rigolon, 2017; Xiao, Wang, Li, & Tang, 2017; You, 2016). Large amounts of empirical evidence in developed areas can be found but the conclusions

drawn are varied. Scholars found low economic conditions and ethnic minorities commonly have access to fewer areas of green space as well as green spaces of poorer quality than those of advantaged groups (Dai, 2011; Rigolon, 2016; Talen, 2013). Some arrive at a converse conclusion, i.e. that vulnerable neighborhoods (such as those with low-income or high-minority levels) are not deprived of park amenities (Abercrombie et al., 2008).

Among the emerging case studies in Chinese cities, scholars have also generated varying results. Choosing Shanghai as a case study, Xiao et al. have detected that marginalized groups seem to be provided with more urban green spaces than wealth residents (Xiao et al., 2017). Similarly, You found strong inequality of accessing public green spaces among different socio-economic groups in Shenzhen, where poor residents with lower levels of housing and employment are provided with insufficient amounts of green space areas but better quality spaces, while the quality of green spaces in wealthier neighborhoods is poor (You, 2016). To the contrary, Wei argues that differences in levels of access to parks and green spaces among different social groups are not statistically significant in Hangzhou, China (Wei, 2017).

1.2.2.3. Perception and Preference

Scholars also debate whether the demographical, socio-economical, and even psychological factors of potential residents might influence preferences and perceptions of people's demand for accessibility to urban green spaces (Park, 2016; D. Wang, Brown, Zhong, Liu, & Mateo-Babiano, 2015). Significant differences on perceived accessibility to, demand for, and preference of urban green spaces have been found across socio-economic groups, relying on factors such as gender, age, education, and occupation in

studies worldwide and using research techniques such as semi-structured interviews, questionnaire surveys, and site observations (Jim & Shan, 2013; Kabisch & Haase, 2014; Riechers, Barkmann, & Tschardtke, 2018; Wright Wendel, Zarger, & Mihelcic, 2012).

1.2.3. The Temporal Dimension: Transition and Interaction

The urban environment is not static. And yet, the majority of literature on urban environments only addresses single or isolated sections of our constantly changing urban settings. Greening activities, which continually alter today's human-nature coupled environments, not only change the geo-spatial configuration of our built environments but also affect socio-spatial patterns through direct or indirect means, including dislocation, segregation, and gentrification. Understanding the temporal dynamics of socio-spatial patterns can better help to unravel the (in)equalities of access to the many different benefits of urban green spaces and their driving factors.

1.2.3.1. Trends and Trade-offs of the Multiple Benefits of Urban Green Spaces

A large volume of scholarly literature from the field of urban ecology and land use studies has observed the spatiotemporal dynamics of vegetation, in most cases by using multi-year remote sensing imagery (B. Zhang et al., 2017; Zhou & Wang, 2011), and through which the driving factors related to urban sprawl, policy, and planning are discussed. However, few studies have linked changing green spaces to potential users and thus are unable to discern the different benefits of green spaces they might access. Limited studies can be found comparing access to certain urban green spaces of social groups in different years. Wei used the Gaussian-based 2SFCA method to evaluate park accessibility at sub-districts (the "Township" scale) in Hangzhou, China, highlighting that

relationships between the changing accessibility to parks and socio-economic groups over the past decade are statistically nonsignificant (Wei, 2017). A similar longitudinal study conducted in Yokohoma, Japan, suggests that parks are more frequently found among affluent populations, though the link is relatively weak (Yasumoto, Jones, & Shimizu, 2014).

These longitudinal studies hardly acknowledge the heterogeneity of green spaces and usually focus on certain types of green space, such as parks or public open space, and often apply a single measurement approach. In other words, green space is considered a universal public resource, providing individual ecosystem services, such as recreational benefits, in those cases measured by accessibility. However, further studies need to differentiate between the multiple benefits or ecosystems services of green spaces including but not limited to parks alone. Parks and public green spaces also offer regulation functions such as air purification, in addition to the recreational benefits, which should be measured in different ways. Other green spaces such as farmland and forests can deliver similar environment-regulating benefits for the public, and thus also need to be examined. In order to gain a holistic understanding of how different benefits are distributed across different social groups throughout time, as well as the trade-offs among these benefits, all possible vegetation types need to be involved in the study.

1.2.3.2. The “Green Paradox” Concern

Human interventions in the urban environment, in turn, can impact socio-spatial patterns. Adding green spaces to mitigate environmental inequality might lead to undesirable outcomes, or what has been called “green paradox,” a concern of many recent scholars (Dooling, 2009; Gould, 2017; Heidkamp & Lucas, 2013; Wolch et al.,

2014). This is because many urban reforestation projects improve the environmental quality of the adjacent communities, but this has the consequence of increasing housing and living costs that are often too expensive for the poor who currently live in those communities, thus keeping them from accessing upgraded environmental quality. Such green space-associated gentrification or dislocation harms the original purpose of urban greening projects, which aim to equally serve the public good; and this has been an emergent issue in recent decades.

Empirical evidence has confirmed these concerns. Scholars in the western world agree that green space-related development leads to gentrification, relying on mixed indicators such as official census data (Anguelovski, Connolly, Masip, & Pearsall, 2017), real estate development (Immergluck & Balan, 2017; Zheng & Kahn, 2013), the number of high-end shops and restaurants (Papachristos, Smith, Scherer, & Fugiero, 2011), media reports (Barton, 2014), and geo-tagged street images (Hwang & Sampson, 2014), to prove these claims. Yet, most of this research discusses the social dislocation effects of individual projects at the neighborhood scale.

In China, beginning in the early 21st century, there has emerged a number of studies showing that urban gentrification comes along with urban renewal and redevelopment. The majority of current studies involve the socioeconomic and political mechanisms of gentrification with respect to housing and public facility-related urban redevelopment (Arkaraprasertkul, 2017; He, 2012; Huang & Yang, 2017; W. Song & Wu, 2010; W. Song & Zhu, 2011; Tomba, 2017; F. Wu, 2016). There are, however, still a very limited number of studies investigating the counter-productive outcomes of urban greening due to dislocation or gentrification effects in Chinese cities. Zheng and Kahn

(2013) found that place-based investment, in the case of the Olympic Forest Park construction in Beijing, led to an increase in housing real estate development, higher local prices, and the opening of a number of chain restaurants, hence gentrifying the area. Similarly, Wolch et al. (2014) argue that efforts to create more green space in Hangzhou might bring undesirable outcomes due to the effects of this green gentrification. However, it should again be noted that these studies highlight single greening projects rather than the city-wide greening practices, which might vary widely across metropolitan areas. Additionally, the gentrification or dislocation effects of green spaces are not examined in most cases. It is entirely possible that green spaces with different features such as a larger size or better design might gentrify adjacent areas more in Chinese cities.

1.3. Structure of the Dissertation

The first section reviews intensive literatures on the topics of urban green spaces and social inequalities.

The second section is about background information of urban green spaces in Beijing including the history of development, law and regulations, administration and planning, and recent challenges of making urban green spaces.

The third section is a brief introduction of basic definitions, data handling, and analytical methods involved in this dissertation.

The fourth section examines the spatial pattern of socio-economic groups *vis-à-vis* the distributional pattern of their access to urban green space by answering the following questions:

- How are urban green spaces with different features distributed among social groups in residential communities in Beijing?
- Do provisions of urban green spaces favor more advantaged socio-economic groups?
- If so, what are the attributes and spatial patterns of these urban green spaces and what are the possible explanations for this?

The fifth section investigates the trend of changing accessibility to urban green spaces in different socio-economic groups between the years 2000 and 2010. The following questions will be answered:

- Are more urban green spaces provided to advantaged socio-economic groups?

- If so, what are the attributes of these urban green spaces and their spatial patterns?
- How is the trade-off of different benefits of urban green space among different social groups distributed for the given period?

The sixth section focuses on identifying “Green Paradox” effect—adding green spaces might dislocate some marginal groups keeping them from accessing multiple benefits of added green spaces. If such a trend is detected, the attributable factors are further discerned and discussed. The following questions will be answered:

- Does adding new green space gentrify the neighboring communities in Beijing hence dislocating marginalized groups? And if so, how much?
- What are the features and types of new green spaces attributable to gentrification?
- What planning approaches and policies are responsible for green space-associated gentrification?

The seventh section includes summary of findings, implication of this research in planning practices in China, as well as limitations and future studies.

2. Urban Green Space in Beijing

This section starts with outlining the trajectory of the urban green space development in Beijing—the case study city—in terms of its political and socio-economic contexts. The contemporary players involved in urban green space provisioning and management—i.e. administrations, regulations, planning, design, and maintenance—are also introduced. The interrelationships of these elements in urban green space development processes are explained in the following. Drawing on the information established in previous subsections, the discussions in the last extend to current issues surrounding urban greening in Beijing, particularly as it relates to the continuous challenges of environmental constraints, social inequality, and green space implementation.

2.1. A Brief History: Urban Green Space Development in Beijing

Since its establishment as a settlement, Beijing has had a history of using vegetation to serve its residents. The multi-layered green spaces throughout the city grew up from a naturally dense forest area, receiving intensive cultivation throughout its history by such means as privatized garden buildings and reclamation of land for agriculture in feudal societies. Public green space creation started in the early and mid-20th century, though such efforts were largely disturbed and stagnated because of wars and other national political turmoil. In recent decades, urban afforestation has become a major concern of the city. Great improvements could be found in the center city where urban renewal replaced dilapidated spaces with pocket parks and gardens, while the peripheral areas have flourished because of large-scale reforestation projects in the form of countryside parks and forests. The recent history of urban green space development in Beijing can be categorized into five stages, each based on varying political, socio-economic, and cultural conditions.

- The City as Royal Garden and Productive Landscape (before 1912)

Situated on the North China Plain, Beijing was once surrounded by dense forests when it was first established as a settlement during the *Jin* Dynasty, c. 1153 C.E. Increasing populations during the feudal societies turned the forest into productive farmland with numerous supportive hydrological infrastructures, while private and imperial gardens simultaneously thrived, serving the royal family and elites in the center of old city (M. Li, 1997). During this period, private gardens in the northern part of the old city and outskirt palaces in the northwest served the royal families (see Figure 2-3). The peripheral plains surrounding the old city were reclaimed for agricultural production

in which small villages and naturally growing trees were interspersed (see Figure 2-1 & Figure 2-2).

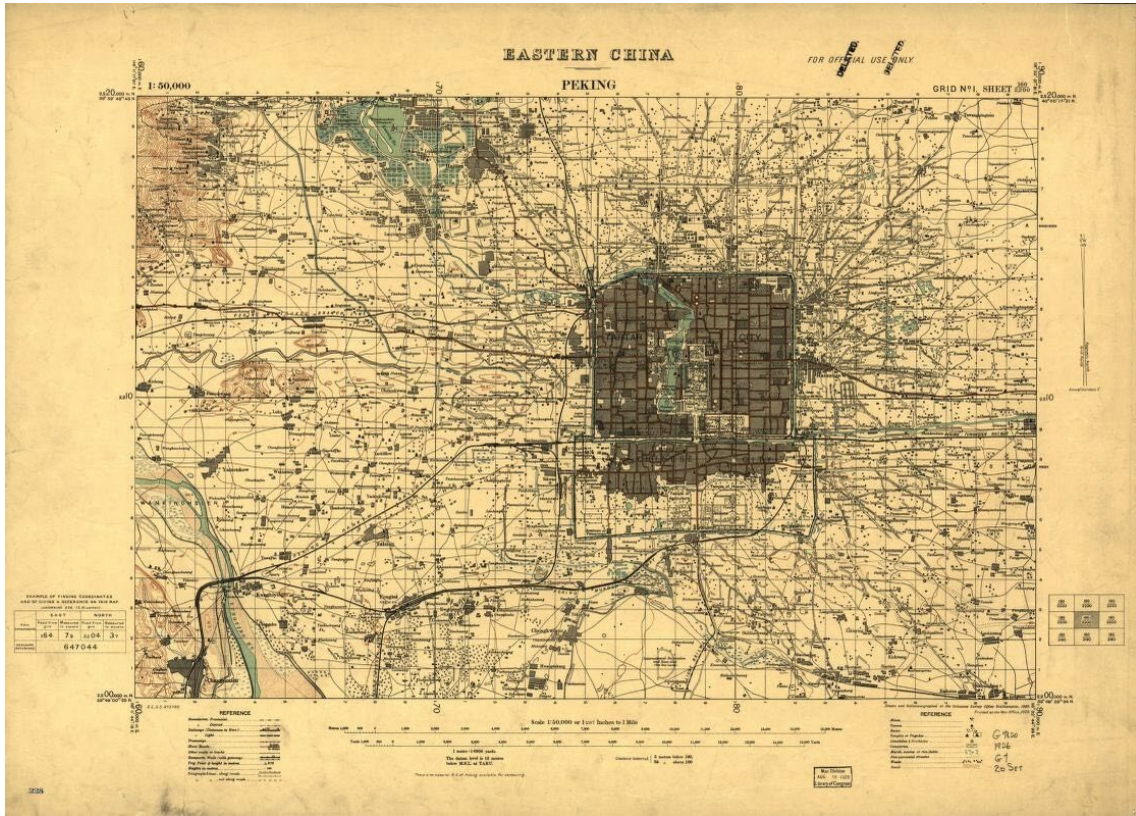


Figure 2-1 Beijing old city and its outskirts in 1926. (Great Britain War Office, Great Britain Ordnance Survey, & United States Army Map Service, 1927)



Figure 2-2 Wanshou Hill, Kunming Lake, and Nanhu Island at Yihe Yuan and fields to the west. (Morrison, 1933)



Figure 2-3 Hall of Prayer for Harvests in Tian Tan. (Warner, 1923)

- From Imperial Gardens to Public Parks (1912-1949)

The concept of the public park was first imported from the Western World at the end of the *Qing* Dynasty, though these parks initially served only elite groups (Jijun Zhao, 2008). Constructing new public parks, planting street trees, and opening the private and imperial gardens to the public started to emerge during the republic era, serving as a prelude to the urban green space development of modern Beijing (Beijing Local Chronicles Compilation Committee, 2000). However, these efforts generally moved forward at a slow pace due to decades of internal and external war and conflict, thus resulting in only minor changes to the existing patterns of green space in Beijing.



Figure 2-4 The Forbidden City and the periphery areas of Beijing. (21st (Photographic Reconnaissance) Squadron (USAAF), 1945)



Figure 2-5 Street trees in Dong Zhi Men Area. (Beijing Local Chronicles Compilation Committee, 2000)

- Recovery and Adjustment Period (1950-1980)

At this stage, the Beijing government prioritized quantity over quality of urban greening, largely due to the limited budget and resources of the war-torn country (Beijing Local Chronicles Compilation Committee, 2000). Heavily impacted by a series of political events during the period such as "Great Leap Forward (*Da Yue Jin*)²" and the "Cultural Revolution (*Wen Hua Da Ge Ming*)³" as well as three consecutive years of natural disasters, Beijing's urban greening activities were guided by multiple changing regulations and a generally tumultuous path.

As a subcomponent of the first urban master plan, the major aims of the 1954 version of master plan regarding urban greening (see Figure 2-6) were: 1) to preserve water and soil resources, 2) to ensure ongoing agricultural production, and 3) to guarantee environmental quality for heavy industrial productions to be built around the

² Great Leap Forward: An economic and social campaign initiated by the Communist Party of China (CPC) from 1958 to 1961. The campaign was led by Mao Zedong and aimed to rapidly transform the country from an agrarian economy into a socialist society via fast industrialization and collectivization.

³ Cultural Revolution was a sociopolitical movement that took place in the People's Republic of China from 1966 to 1976. The movement paralyzed China politically and negatively affected the country's economy and society.

old central city in the southern areas in the first decade after the establishment of this New China (Beijing City Planning Commission, 1954). The early stages of afforestation in Beijing included the continuous opening of royal gardens, extensive building of new parks, and the planting of street trees, all of which increased the overall volume of the city's green spaces. In the later 1958 master plan (see Figure 2-7), the spatial pattern of green spaces manifested as dispersed patches in the gaps between different functional zones, where the central area of Beijing was designated for government, and the northwest and southeast areas for education and industry, respectively (Gu, Wei, & Cook, 2015).

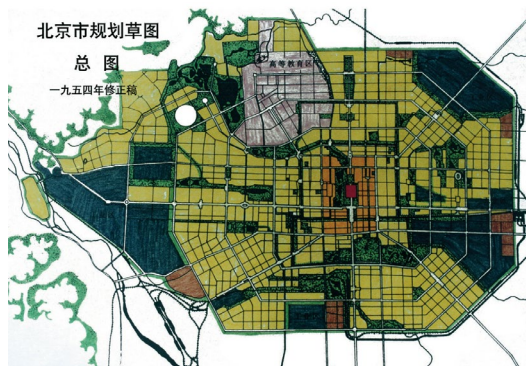


Figure 2-6 Draft of Beijing Master Plan 1954 (Beijing City Planning Commission, 1953)

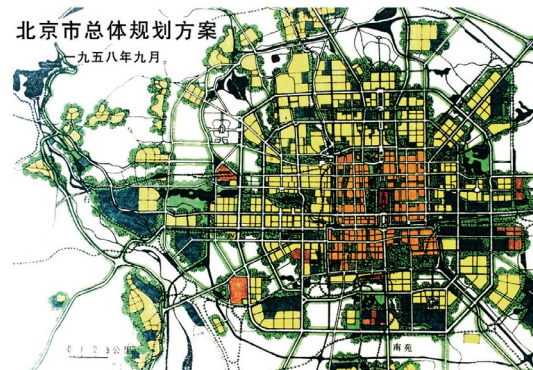


Figure 2-7 Beijing Master Plan 1958 (Beijing City Planning Commission, 1958)

The demand for fast development during the “Great Leap Forward (*Da Yue Jin*)” movement caused over-investment in urban greening activities without sufficient resources for maintenance, which consequently led to low quality green spaces, and the upheaval of the greening practices such as altering public green spaces for agricultural production (see Figure 2-9) during the “Cultural Revolution (*Wen Hua Da Ge Ming*)”

and the three years of natural disasters also further worsening the situation (Beijing Local Chronicles Compilation Committee, 2000). The only subsequent master plan proposed in 1973 (see Figure 2-8)—which highlighted the environmental deterioration caused by the city’s overly developed heavy industry—was ultimately not put into practice, and the earlier configurations of urban green spaces remained without major changes (Y. Wang, 2016a).

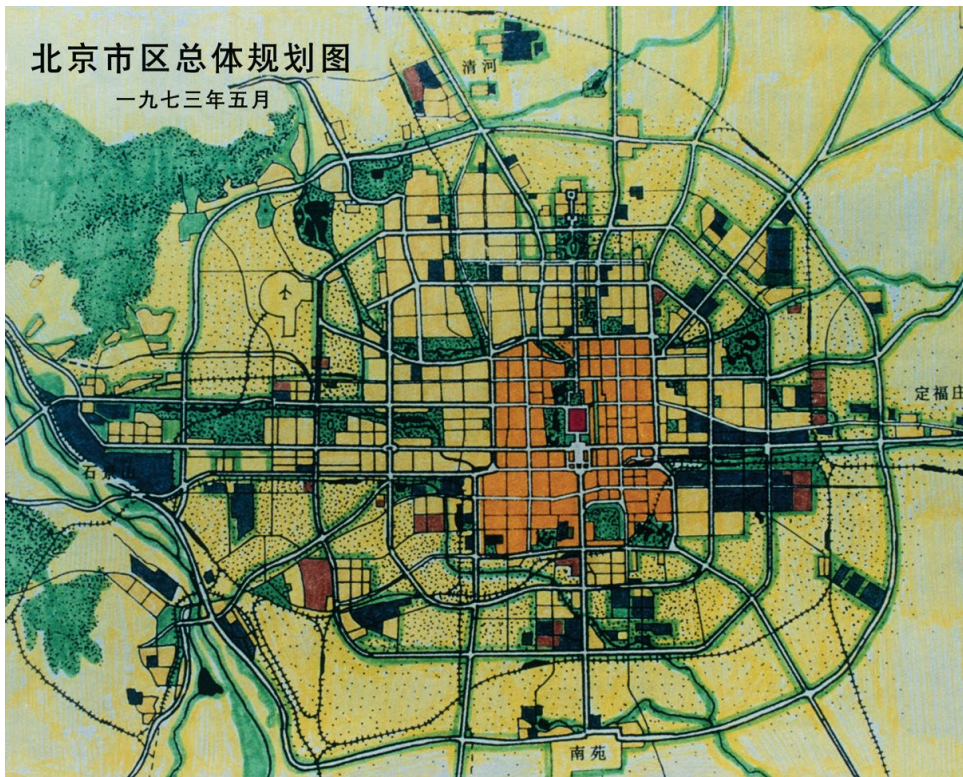


Figure 2-8 Beijing Master Plan 1973 (Beijing City Planning Commission, 1973)

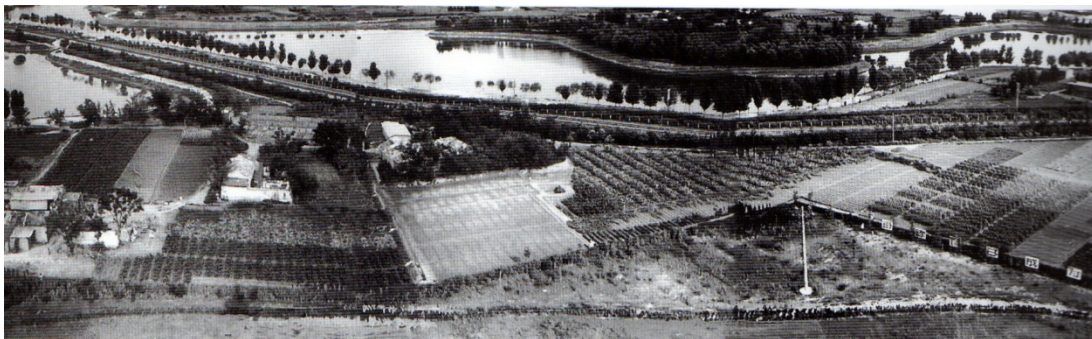


Figure 2-9 Parks trees were replaced by crops for production, Long Tan Hu Park in 1955 (Beijing Local Chronicles Compilation Committee, 2000)

- Rehabilitation Period (1980-2004)

After the Government adopted the “Open and Reform (*Gai Ge Kai Fang*)” policy in the late 1970s, the country started to focus on economic development, which meant deprioritizing heavy industry of the city. The Beijing municipality was required to improve the environment and sanitation quality of the city in which building urban green spaces served as a major tool. With support from the national and municipal governments in all related aspects, Beijing’s urban green spaces were improved in both quality and quantity (Beijing Local Chronicles Compilation Committee, 2000). The Beijing Master Plan 1980-2000 (see Figure 2-10) stressed the importance of building a “Clean, Beautiful, and Ecological Sound” capital (Beijing Municipal Commission of Urban Planning, 1982), and the successive master plan of 1992 (see Figure 2-11) was adjusted to accommodate the following two concerns: first, the rapidly growing population that exacerbated environmental burdens, and second, to ensure coordination among diverse land use projects, such as hotels, shopping centers, and cultural and exhibition centers to attract more foreign investment (Beijing Municipal Commission of Urban Planning, 1992; Gu et al., 2015). Dozens of new parks were raised in the center city and suburbs, while residential, transportation, and institutional land uses were surrounded with more vegetation (Beijing Local Chronicles Compilation Committee, 2000).

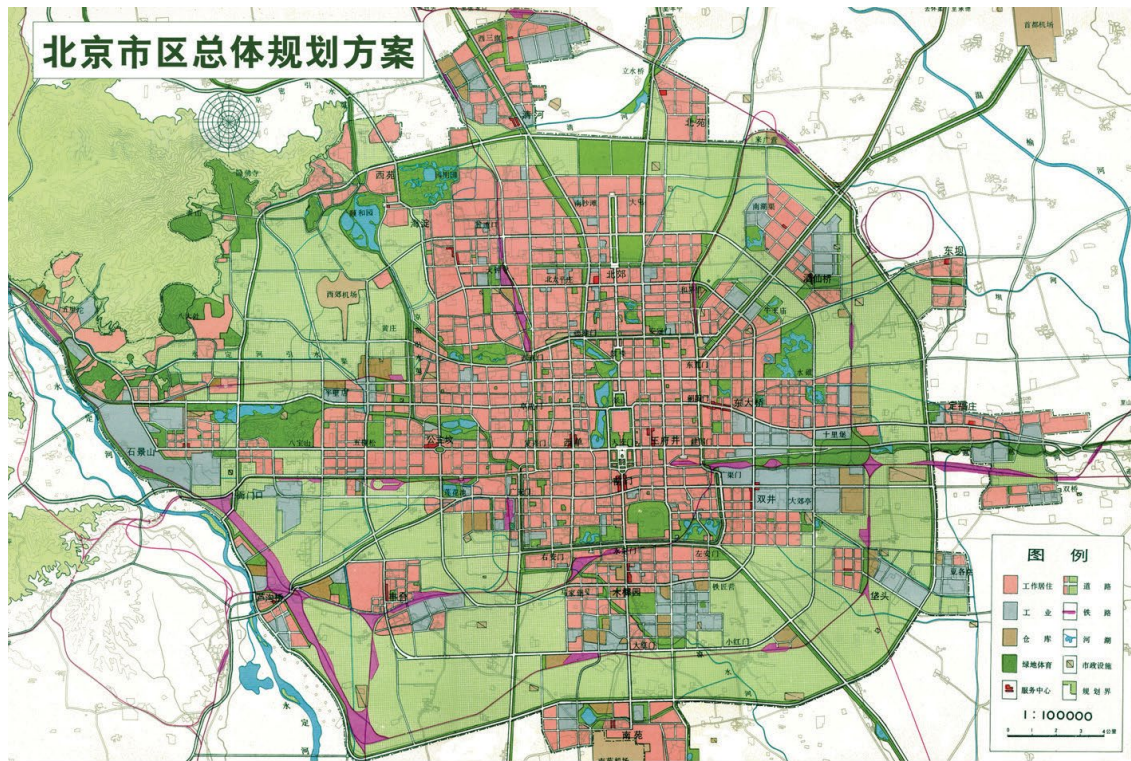


Figure 2-10 Beijing Master Plan 1982 (Beijing Municipal Commission of Urban Planning, 1982)

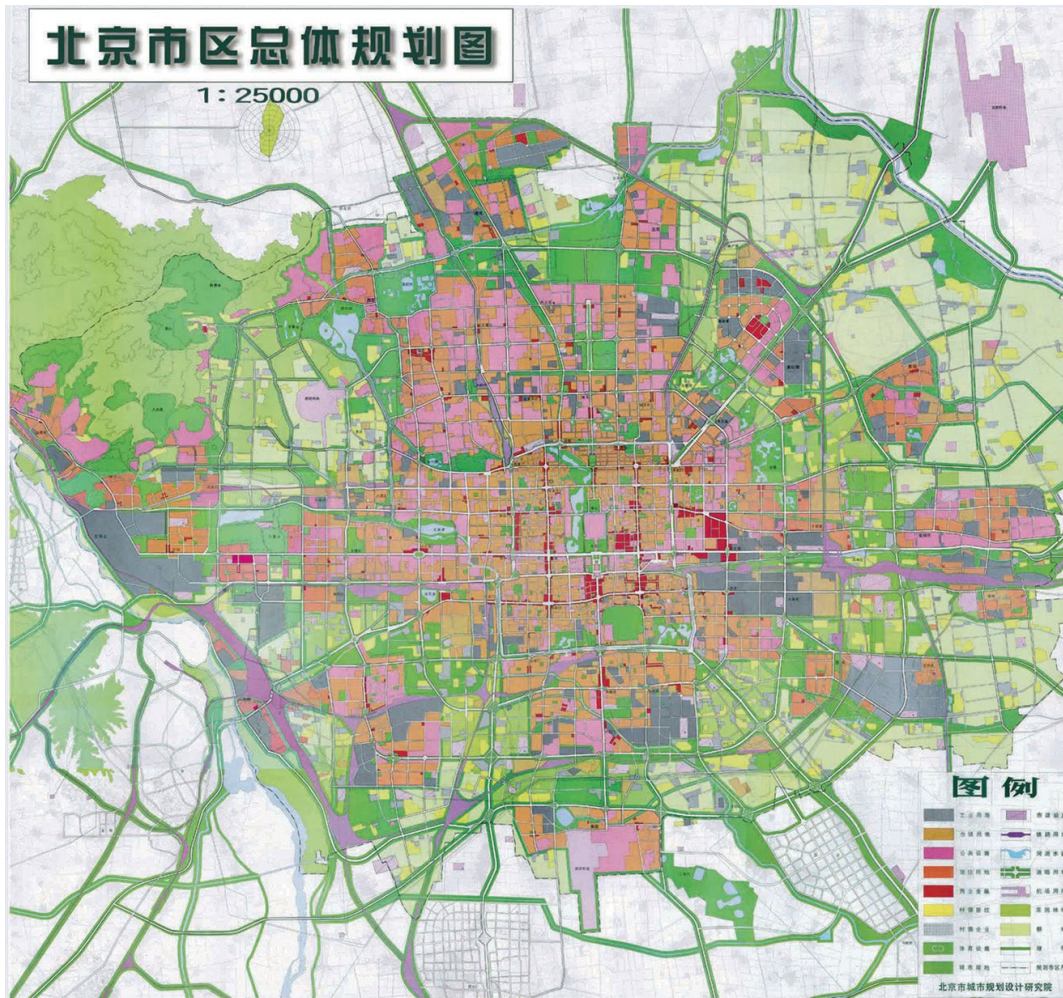


Figure 2-11 Beijing Master Plan 1992 (Beijing Municipal Commission of Urban Planning, 1992)

- Prioritizing Urban Greening (2004-present)

In the early 21st century, Beijing was confronting more severe environmental deterioration while at the same time embracing global cooperation in multiple economic and cultural respects. Starting in this period, improving the quality and functionality of green spaces while increasing their quantity has become an urgent task for urban planners in Beijing. After the country was permitted to join the WTO in 2001 and won the eligibility of hosting multiple international events, such as the 2008 Olympic Games, the city was required to further address its environmental issues and create high quality urban

landscapes by adding more diverse green spaces (see Figure 2-12). In 2004, a comprehensive planning of urban green space (see Figure 2-13), proposed by the Beijing Municipal Institute of Urban Planning and Design, intended to meet the demand of this new era by increasing the amount of green spaces at various scales, from the neighborhoods of the inner city, to the outskirts of the city (Beijing Municipal Institute of City Planning and Design, 2007).



Figure 2-12 Olympic Forest Park for both hosting the 2008 Game and serving local residents. (Tsinghua Urban Planning and Design Institute, 2015)

北京城市总体规划（2004年-2020年）

图07 中心城用地规划图

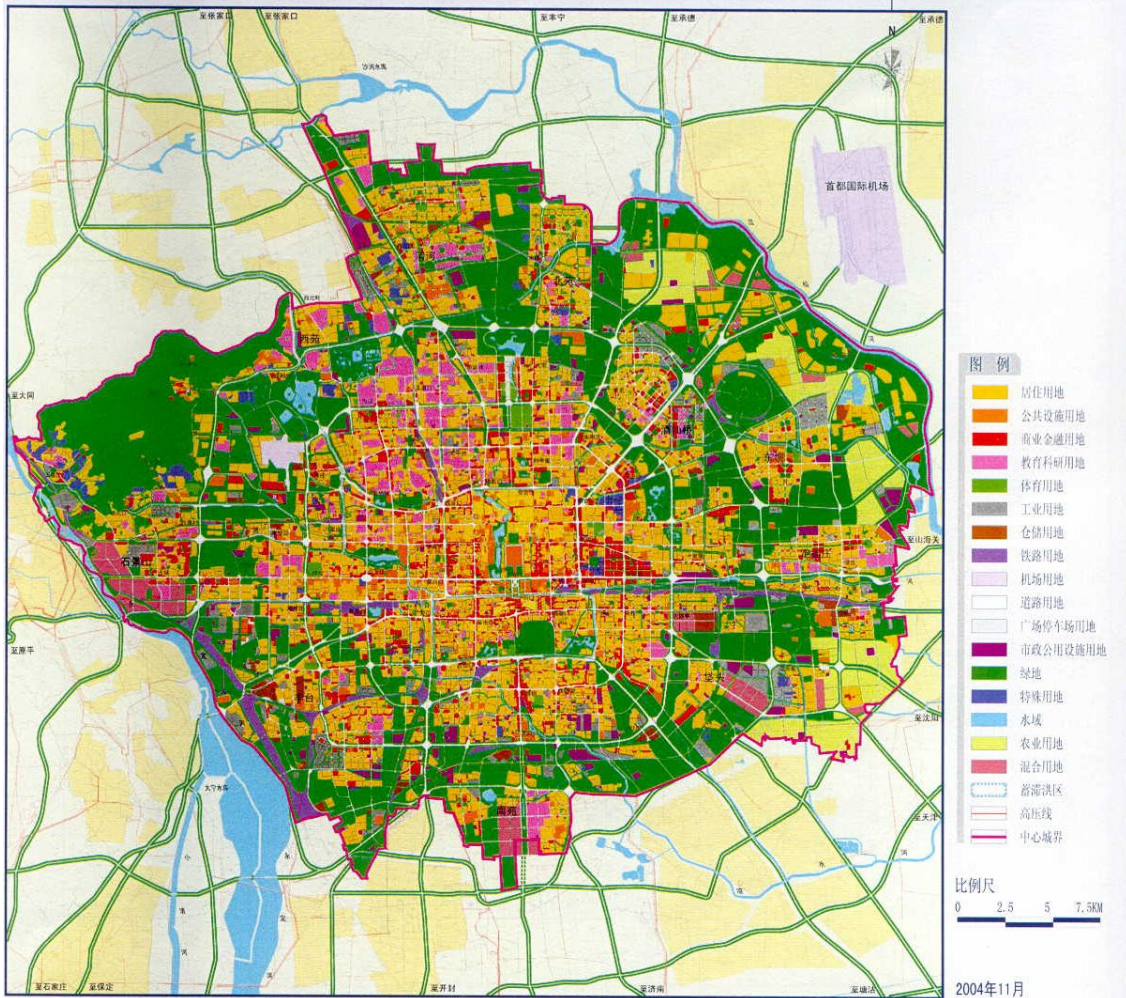


Figure 2-13 Central City Land Use Planning of Beijing Master Plan 2004-2020 (Beijing Municipal Institute of City Planning and Design, 2007)

The recent prioritization of green space planning also is an attempt to stop development from encroaching on pre-existing green space projects, particularly by producing more effective green spaces patterns. This has been achieved by increasing the connectivity between green space patches and enforcing strong safeguard regulations. Previously, two levels of greenbelt were proposed in 2003 with the aim of controlling urban sprawl and alleviating the environmental burdens that followed, but these efforts

were soon hampered by real estate development (F. Li, Wang, Paulussen, & Liu, 2005). The successive 2004-2020 Beijing Urban Master Plan adopted a “wedged” pattern (see Figure 2-14), consisting of larger suburban natural parks and more infrastructure-affiliated linear green spaces, which then link with inner-city green patches and corridors to form a “green network”. This was done with the aim of providing multiple services to the public and supplementing green areas occupied by development. (Beijing Municipal Institute of City Planning and Design, 2007). The recently posted 2016-2035 Beijing Urban Master Plan proposes to strengthen such patterns by introducing more diverse parks and forests at the periphery (see Figure 2-15) as well as reinforcing their interconnectedness by building multiple greenways consisting of boulevards, linear waterfront green spaces, and dense buffer forests along arterial roadways, all in an effort to link the separated park patches together to improve the ecological and recreational benefits to the city. In an attempt to safeguard the volume of already developed green spaces, policies and regulations such as “Ecological Conservation Red Line” have been proposed to prevent green spaces from any encroachment activities (Capital Greening Office, 2017).

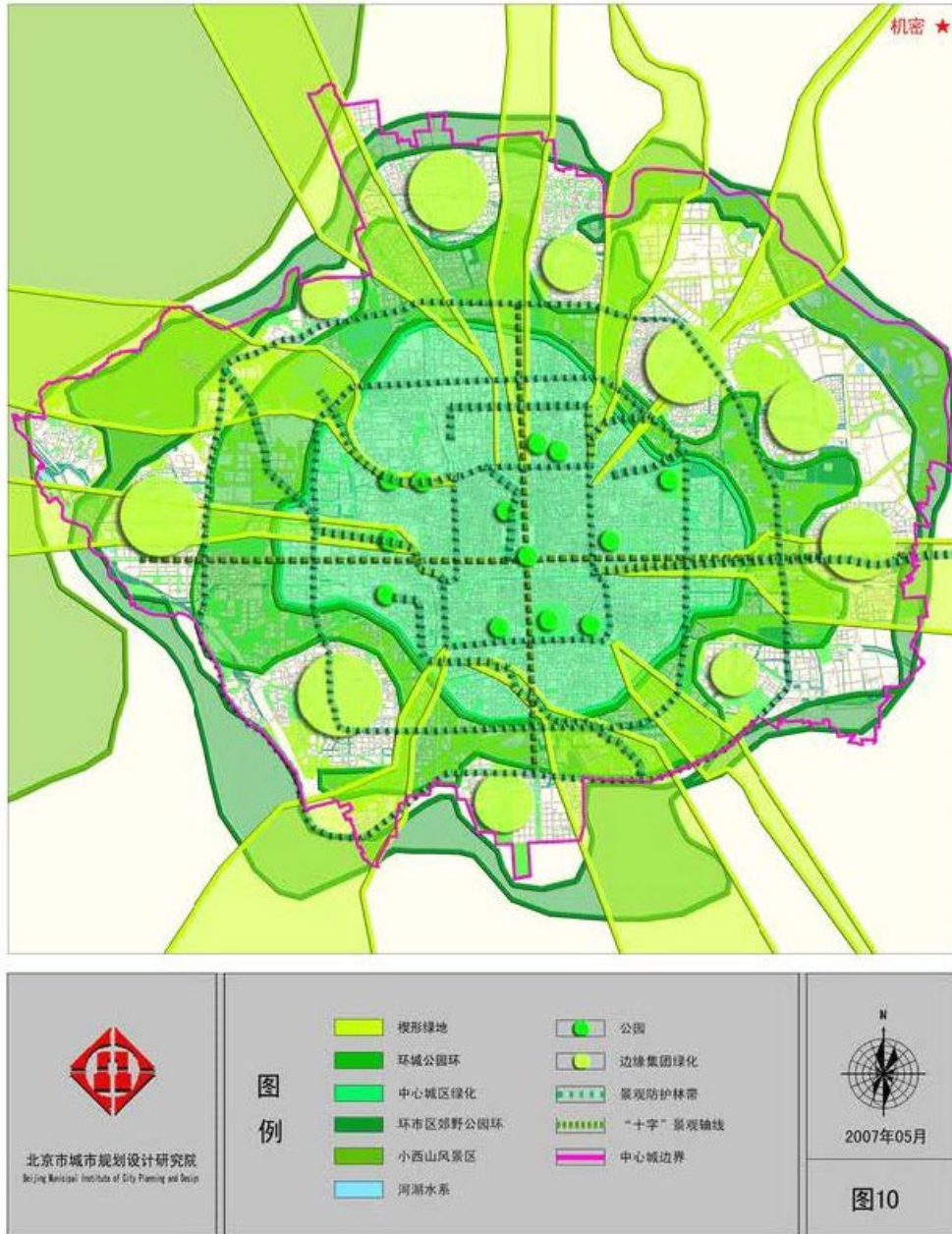


Figure 2-14 The conceptual structure of urban green spaces of Beijing Master Plan 2004-2020 (Beijing Municipal Institute of City Planning and Design, 2007)

北京城市总体规划（2016年—2035年）

图12 中心城区市级绿道系统规划图

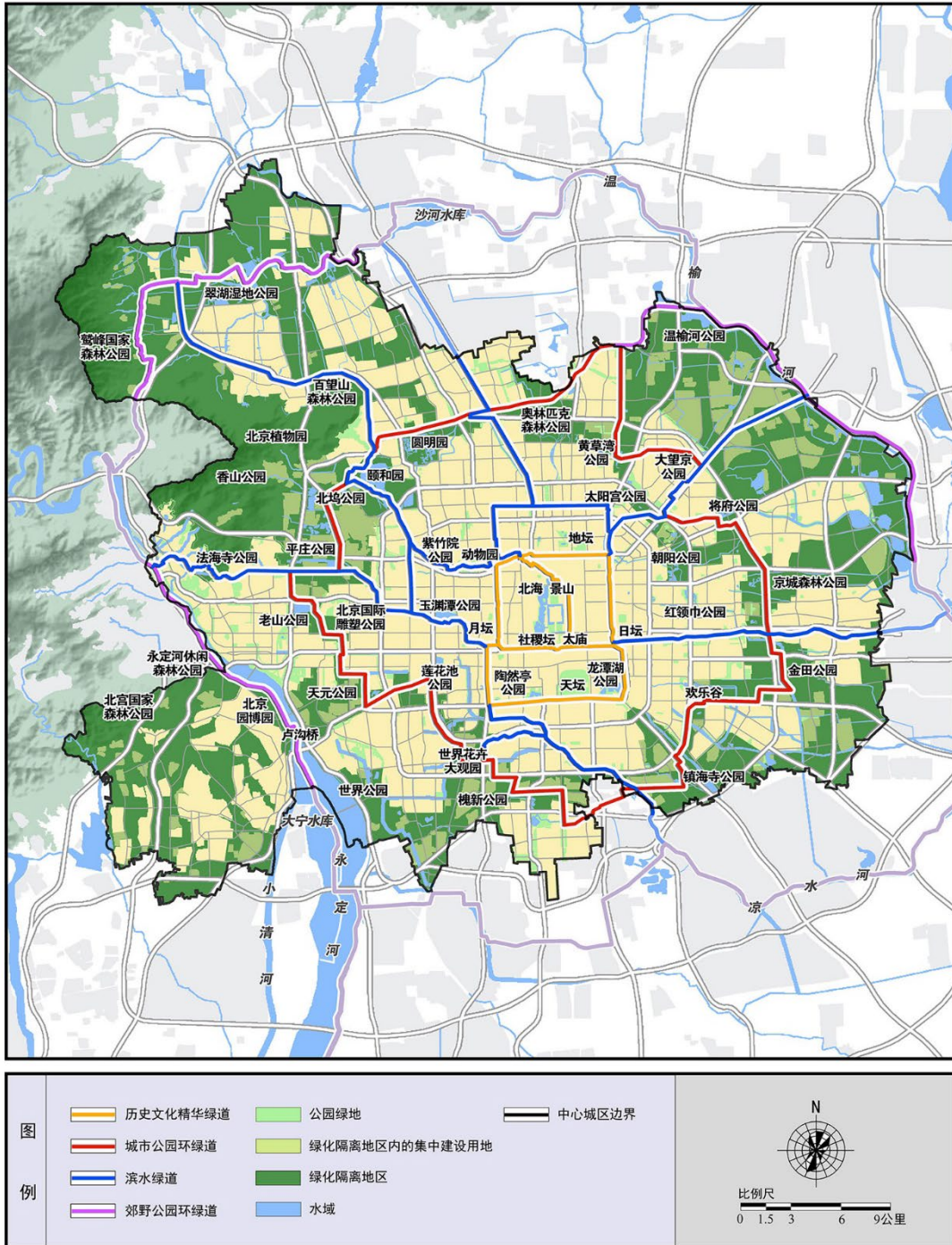


Figure 2-15 The urban green spaces network of Beijing Master Plan 2016-2035 (Beijing Municipal Bureau of Land and Resources, 2017)

2.2. Processes and Players of Urban Greening in Beijing

2.2.1. Regulation and Administration

Urban green space planning and design in China are centralized, top-down processes. The urban green space plan is still a sub-plan of the upper level urban master plan and is called a “special plan.” The development of such special plan is based on multiple relevant regulations and government guidance documents at both the national and local levels. The national, municipal, and district administrative governments organize the green space plans by assigning different aspects of the work to each administrative level, which are mostly done by public institutes cooperating with other related departments of city and local governments. Aspects, such as the design, implementation, and maintenance, can be assigned to both public and private sectors.

Under the supervision of the Beijing Land and Resources Management Committee (BLRMC), the Beijing Municipal Institute of City Planning and Design (BMICPD), a municipal public planning institution, plays a major role in establishing Beijing urban green space planning (Beijing Municipal People's Congress, 2009). The greening bureau of the various subdistricts are responsible for inviting planning institutes to work out the green space plan at subdistrict levels. Multiple departments, such as transportation, water, and fire authorities, collaborate with the planning institutes in making the urban green space plan. The plan needs to be examined and approved by the People’s Government of Beijing for further implementation and is then included in the urban master plan. Even though the plan development phases include public participants, such as plan publicity and professional consulting, public participation is more about providing input to make minor adjustments than making critical decisions.

2.2.2. Urban Green Space Planning, Design, and Maintenance

The sectors that monitor the design, implementation, and maintenance of green spaces come from either the public or private domains, depending on the type of land use in question. Public green spaces, such as parks, wetlands, and countryside forest parks, are managed by the Garden and Greening Bureau in each district; green spaces attached to or alongside roads, railway lines, and rivers are managed by respective departments of the municipality. For example, the Beijing Water Authority manages green spaces within and around rivers or lake borders; affiliated green spaces within areas, such as university campuses and commercial or residential land use areas, are managed by the units who have the right to use or develop those lands (Capital Greening Office, 2010).

The design of urban green spaces is assigned to qualified public or private design institutions through commission or invitation to bid by the abovementioned managing or developing units of land parcels. The design of urban green space follows the respective regulations according to the land use codes. For example, if a land parcel is coded as an urban park, the design has to follow the park design and planning related regulations, such as “Code for Design of Parks (Capital Greening Office, 2016).” Additionally, the upper level urban green space plan and regulations in other related departments are also required to be considered in the designs (Capital Greening Office, 2010). Certified construction groups specializing in landscape architecture carry out the construction of green spaces, along with various additional material and plant suppliers. Generally, the construction teams or plant providers maintain the quality of vegetation for a certain “guaranteed period” after the construction. When the guaranteed period expires, the respective land parcel managers are responsible for maintaining works (Capital Greening Office, 2010).

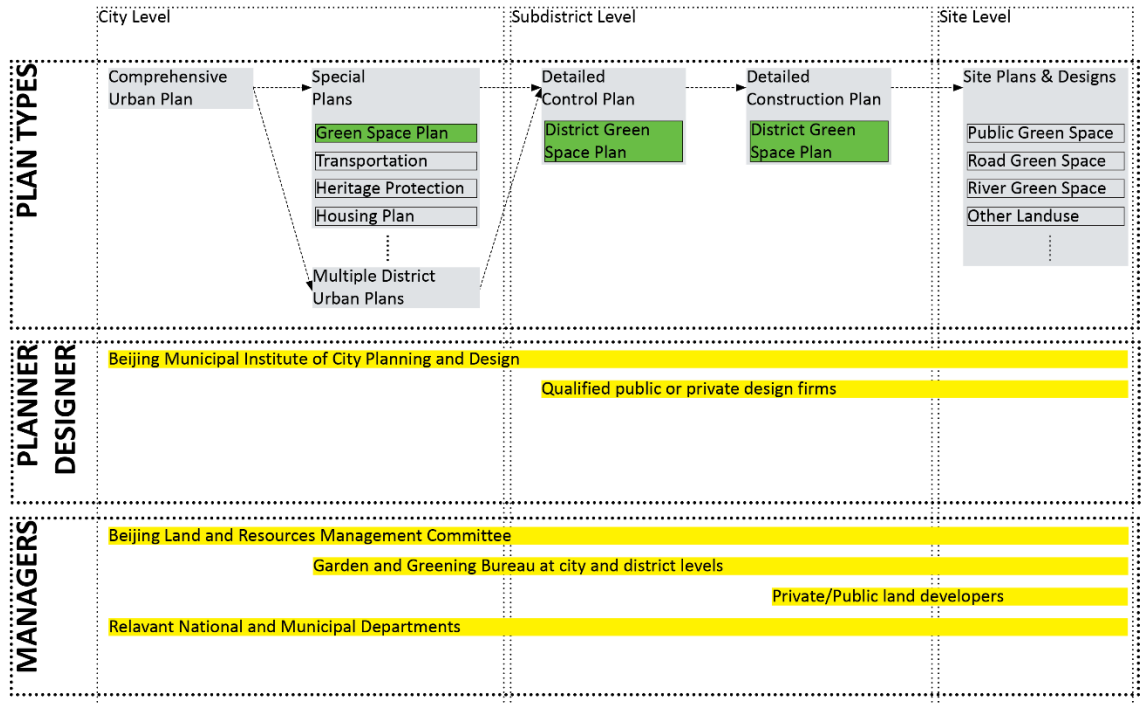


Figure 2-16 The processes and players of urban greening in Beijing.

2.3. Recent Status and New Challenges

2.3.1. Current Resources of Urban Green Spaces in Beijing

With a green coverage rate⁴ of 48.42% citywide in 2017 (Capital Greening Office, 2017), Beijing is among the most greened cities in China, both in terms of the quantity and quality of its green spaces. The northern and northern-western mountainous areas have the highest area of green spaces, mainly in the form of historical gardens and well-protected forests; and the southern area has protective forests and countryside parks dispersed among patches of built areas and agricultural lands. The central city (the area within the 2nd ring road) features numerous ancient palaces and modern parks.

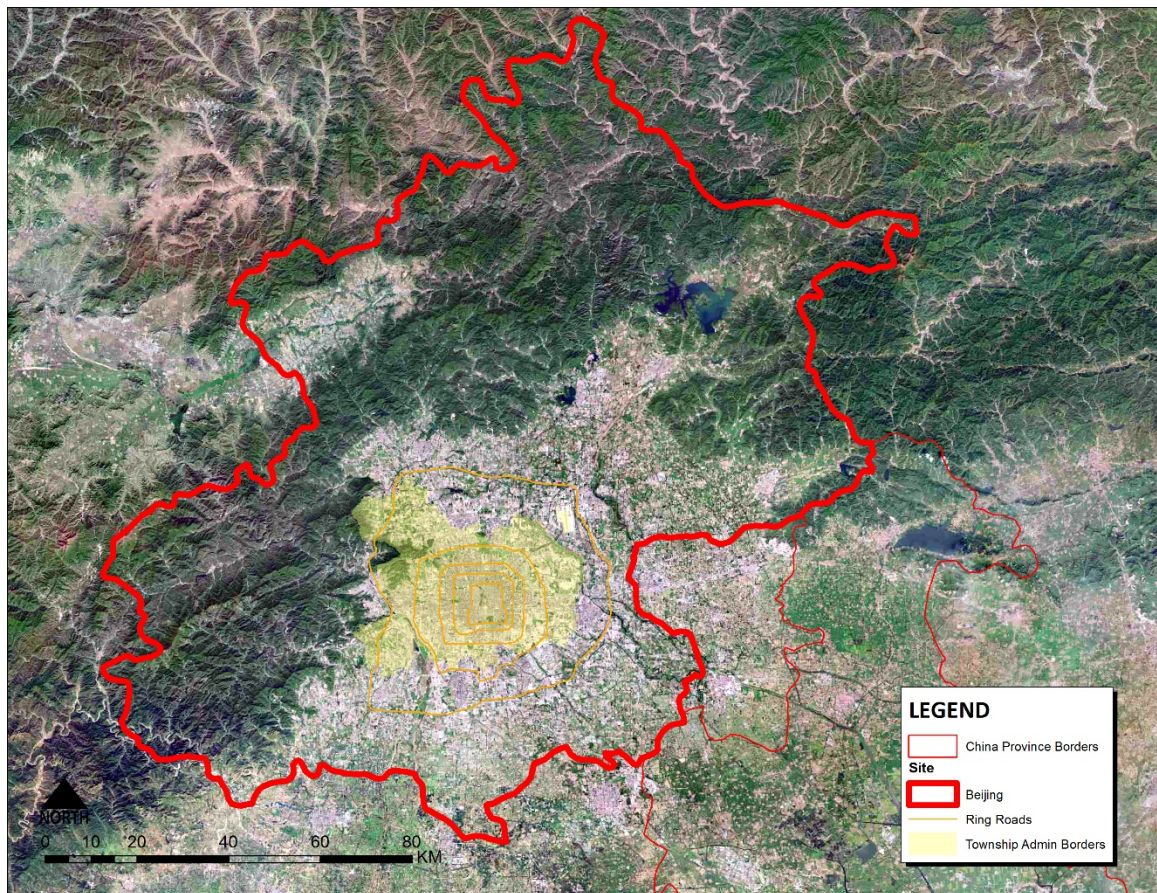


Figure 2-17 Satellite image of Beijing. (Gaode, 2018).

⁴ Green coverage rate: projected leaf area on the ground divided by urban land area.

Though the total amount of green space has been increasing over the past decades (see Figure 2-18), the spatial distribution of such space is suffering from unbalanced development: the outskirts have more green space compared to the inner city. Areas in the periphery of the center city (within the 2nd ring road) and urban regions in suburban and county districts are even suffering a loss of green spaces (X. Xu, Duan, Sun, & Sun, 2011) due to intensive urban development and sprawl.

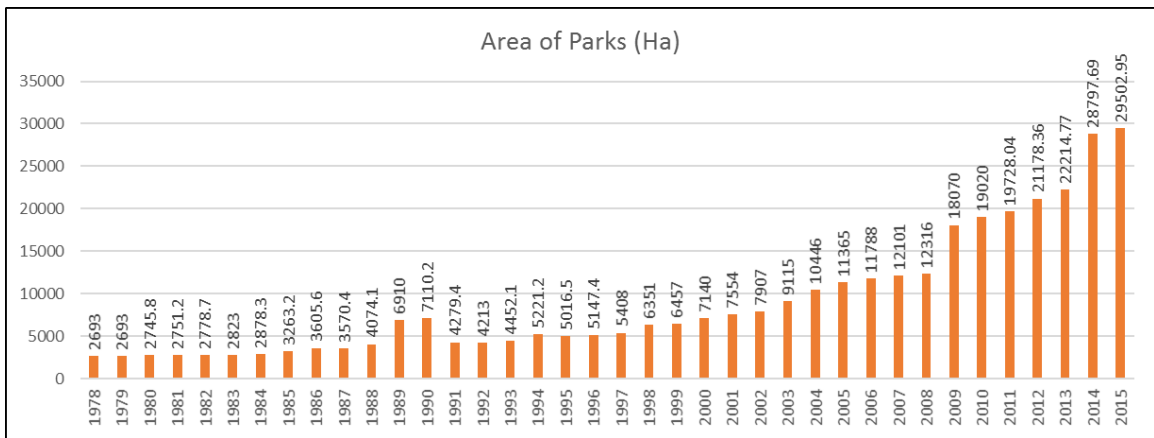


Figure 2-18 The total area of park green spaces in Beijing 1978-2015 (Capital Greening Office, 2017)

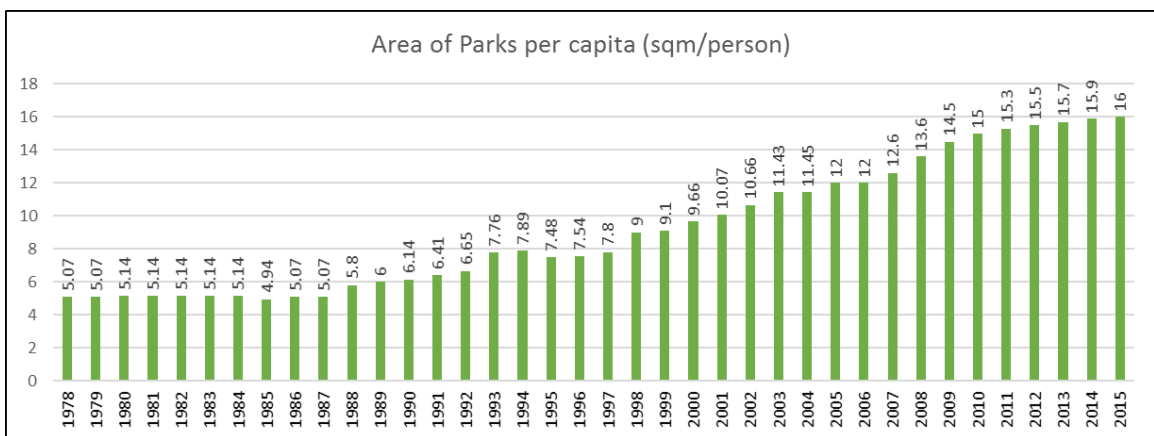


Figure 2-19 The area of park⁵ per capita 1978-2015 (Capital Greening Office, 2017).

⁵ The parks are those public green spaces open to the public with a green coverage rate above 65%.

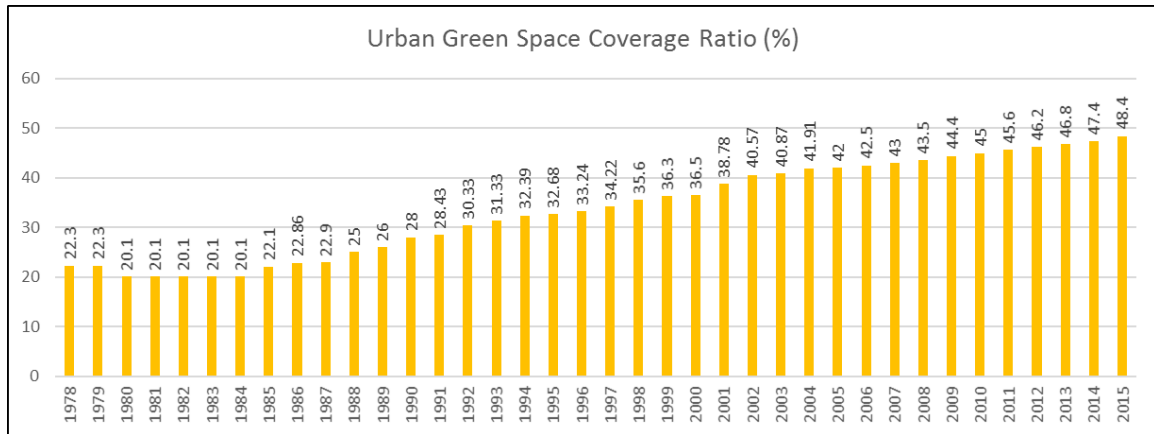


Figure 2-20 The urban green space coverage ratio⁶ in Beijing 1978-2015 (Capital Greening Office, 2017)

Discrepancies among green space provision in areas with varying socio-economic conditions exist, though this has not been studied thoroughly. In Yao et al.'s research on the public's access to green spaces in Beijing, the *Feng Tai* district was observed to have less public green spaces than the other five city center districts (Yao, Liu, Wang, Yin, & Han, 2014). However, aside from this, few studies have investigated how socio-demographical factors associated with green spaces affect their provision at the city scale, especially during the past decades in Beijing. Furthermore, though the government attempts to add green spaces equally to respond to the many needs of different social groups, one of the paradoxical consequences of investing in green space is its tendency to displace the original residents who can no longer afford the increased environmental amenity costs that result from the introduction of green space.

Although serving as an affiliation in the comprehensive urban plan, green space planning has steadily received increased attention given its capacity to deal with environmental problems at multiple scales. The changing institutional framework of

⁶ The urban green space coverage ratio: total area of green spaces divided by urban area.

planning, as well as policies emphasizing the importance of ecological security and sustainable development, are rendering green space planning an important role in urbanization.

2.3.2. Confronted Challenges

Though the Beijing Municipality, like many other Chinese cities, is striving to increase the volume of green spaces, such efforts are still challenged by many factors, including the growing demands of population and environmental pressures; the cumbersome administrative procedures and limited regulatory enforcement; the conflict between economic development and environmental protection; the lacking of proper planning techniques; and finally, the uneven development of green spaces across the city.

2.3.2.1. Environmental Pressures and the Increasing Demand for Green Spaces

Increasing population density and sprawl of urban built-up areas put pressure on both the natural as well as the public resources of the city. The environmental issues concerning soil and water preservation, air quality improvement, heat island prevention, as well as biodiversity and habitat protection have become major concerns of the government and associated urban planning sectors (Yu, Wang, & Li, 2011). Beijing's recent census reported that the city's population is as high as 19.6 million in 2010, well above the planned population of 18 million that was expected by 2020 (Z. Yang, Cai, Ottens, & Sliuzas, 2013). The overall volume of urban green spaces has gradually increased in the past decades but the area of public green spaces per capita is still relatively low (16 square meters at the end of year 2015, see Figure 2-19), especially when compared with other cities of a similar size, such as 28.3 sqm in New York City

(Beijing Bureau of Statistics, 2017; New York City Department of Parks & Recreation, 2019). Green space coverage in urban areas has also increased from 22% in 1978 to 47% in 2015 (see Figure 2-20). However, the spatial distribution is uneven across the city where most forests areas are concentrated in the north and northwest mountainous areas (Beijing Bureau of Statistics, 2017). Confronting the continuously increasing environmental stress factors, the city has begun to demand corresponding investment in urban green spaces.

2.3.2.2. Administrative, Regulation, and Financial Obstacles

There are also many challenges facing both the financial and administrative sectors, which have failed to safeguard existing green space resources and hindered the installation of green spaces in desirable locations. Due to the pressures of real estate development, the areas available for adding more green space in urban areas are becoming increasingly limited, and original green space land use is often altered into urban development (M. Li, 1997). This is, on the one hand, because of the late implementation and lack of regulatory enforcement of green space protection policies. Without sufficient means of enforcement, regulatory agencies are incapable of preventing existing or added green spaces from being encroached upon by profit-driven development. The developed area of Beijing, as determined in the 1992 Urban Master Plan, has already been exceeded by the addition of numerous development projects, encroaching upon vast quantities of green space, agricultural land, and forests (F. Li et al., 2005). On the other hand, the funding for green space comes from the financial support of the municipalities, which in turn, mostly comes from the income of leasing land. This has led to a significant negative impact on the provision of urban public green spaces, primarily through the fervent attempts of local governments to strengthen

themselves financially and politically through land development and redevelopment (W. Y. Chen & Hu, 2015).

Profit-driven real estate development, for example, has significantly encroached and fragmented the green belt plan proposed in 2003, which has been adjusted and turned into a “wedged” green space pattern in the most recent comprehensive urban plan of Beijing (2016-2035) Master Plan (Beijing Municipal Bureau of Land and Resources, 2017). The result is the elimination of large amounts of green space, which would otherwise be of great benefit to the city. An alternative way of capitalizing green space is by reconstructing current public green spaces into commodity green spaces, such as costly golf courses or high-quality holiday resorts, which provide exclusive access for small wealthy groups. However, even though such alterations maintain certain ecosystem benefits, like air cooling (at an extreme high cost), the public recreational and/or aesthetic benefits are massively degraded.

2.3.2.3. Issues in Planning Implementation

In planning practice, the quantity of green space is prioritized over the quality and spatial features of such spaces (X.-J. Wang, 2009); for instance, decision-makers are focusing on green space area per capita and green ratios in the administrative border of a city (X.-J. Wang, 2009). However, the mere quantity of green spaces does not reflect their spatial distribution nor their quality, which hinders the location-sensitive ecosystem services and benefits intended to be provided by these green spaces.

The lack of proper implementation techniques in planning practices contributes to the aforementioned uneven configuration of urban green spaces in Beijing. Though previous plans mentioned the need to increase people’s access to urban green spaces,

their spatial approach is limited to the likes of using buffer zones of green spaces to determine catchment areas, disregarding the actual walking distances and other barriers to accessing the areas to be treated with green spaces. The most recent urban master plan (Beijing Municipal Bureau of Land and Resources, 2017) mentioned that the 500-meter buffer zone coverage of park green spaces in built-up areas shall be increased from 67.2% to 85% in 2020, and to 95% in 2035, regardless of the actual walking distance and spatial distribution for potential users. Such over-simplified planning approaches fail to properly control spatial configuration, the distribution of various ecosystem services, and the general quality of green spaces at the local level (X. Xu et al., 2011). Finally, it is ended up with adding new green space in any possible urban left-over space in the central densely built-up areas and implementing massive green space in peripheral regions due to the cheaper cost of land reclamation.

2.3.2.4. Spatial and Social Inequality of Urban Green Space Development

Admittedly, the Beijing municipality is striving to increase the volume of urban green spaces in the central built-up areas of the city, as well as in the southeastern flat region. At the same time, attempts at maintaining the quality and quantity of green spaces in the outskirts mountains surrounded by dense forests are also taking place. Increasing urban density calls for a higher efficiency of land use and equity of public amenities, such as public green spaces (X. Xu et al., 2011). But current research—though limited in number—has still identified the trend of uneven spatial distribution of green spaces among city residents, such as *Feng Tai* district has a much lower degree of green space provision than other districts (Yao et al., 2014).

More importantly, merely stressing spatial distribution disregards key socio-economic aspects of the potential beneficiary groups, which might lead to an unequal pattern of urban green space in the city. Wealthier groups can afford higher housing costs in gated residential communities, where well-maintained green spaces are provided exclusively. Planting massive public green spaces close to these high-end communities might expand the inequality of green space provision, further marginalizing those poorer citizens who have limited access to green spaces. This further hampers the delivery of the holistic values of urban green spaces to the majority of the public, especially in a city that demands a higher efficiency of land use—exploiting the most benefits of urban green spaces. Such demand is also highlighted in a recent speech delivered by the nation’s leaders: “...the principal contradiction facing Chinese society has evolved” as mentioned in the 19th CPC National Congress by the president Xi, “What we now face is the contradiction between unbalanced and inadequate development and the people’s ever-growing needs for a better life.” Access to urban green space as a public amenity as well as natural resources should then keep up with the changing demands of people in the urbanization of the new era.

3. Summary of Research Methods and Data

3.1. Defining Urban Green Spaces

Definition of green spaces varies based on the research focuses of different disciplines (Taylor & Hochuli, 2017). In this study, the definition of green space is determined by the direct services provided to the residents in the built urban area, which are recreation and environmental regulating services in most cases (Chang et al., 2017). Therefore, two definitions are adopted in this dissertation: urban public green space and urban vegetation. Public green spaces that provide recreation services in this study include parks, gardens, accessible roads adjacent green spaces, and agricultural tourism gardens that are freely accessible for the public in the built area of Beijing (the six city districts)⁷. Urban vegetation includes all types of plants of parks, farmland, forest, grassland, and street trees are counted to measure the environmental regulating benefits such as soil conservation, runoff mitigation, air purification, cooling, etc. The reasons for redefining green spaces are as follows:

The most recent official classification system in China, the “Standard for Classification of Urban Green Space (CJJ/T 85-2002)” was published by the Ministry of Housing and Urban-Rural Development of the People’s Republic of China (MOHURD) in 2002 (Ministry of Housing and Urban-Rural Development, 2017). This system divides urban green spaces in China into five categories, which are then divided into thirteen subcategories, which are further divided into eleven groups. However, the official system is based on land use types but does not reflect ecosystem services in urban areas.

⁷ The six city districts are *Xi Cheng*, *Dong Cheng*, *Feng Tai*, *Hai Dian*, *Chao Yang*, and *Shi Jing Shan*.

The recreational services of green spaces are highly determined by the accessibility and diverse programs and facilities within. For example, historical parks and buffer forests or linear street affiliated green spaces provide very different recreational services given the varying qualities and design features, given that buffer forests are not designed to allow any recreational activities for residents. Additionally, in the studies on public green spaces, many scholars consider urban green space universal in quality, focusing only on certain types of urban green spaces, such as parks. But not all parks are equally available for public use in many Chinese cities. In Beijing, for example, some of the theme parks, such as the *Huan Le Gu* amusement park or Beijing Zoo, charge high entry fees to visit. Even though these parks are considered public spaces within many studies, they are not available to all city residents. Moreover, the design, vegetation quality, and programs are varying among different parks. As such, these need to be considered in the research.

Regarding the environmental regulating benefits, the government's official classification standard is not capable of discerning the differing levels of environmental improvement of the different type green spaces. As the environmental regulating capacity is contingent on vegetation-related conditions such as types, quality, and seasonality of plants, soil conditions, and local climates etc., the government's categorizing system of land use types is a laborious and inefficient categorical tool for measuring the regulating benefits. Many studies conducted in other cities rely on integration of land use maps, remote sensing images and field survey data, (Kremer et al., 2016; L. Yang et al., 2015), a potentially more comprehensive method. Finally, the detailed official classification map

of green spaces in Beijing is not available to the public, meaning outside researchers cannot assess the green space maps to identify the types.

3.2. Identifying Marginalized Socio-economic Groups

Previous studies rely on socio-economic variables, such as median household income, demographic structure, ethnicity, migrant status, home ownership rate, commercial housing sales, and rents (D. Wang et al., 2015; Wei, 2017; Xiao et al., 2017; You, 2016; Zheng & Kahn, 2008). Although income is always one of the most effective indicators for identifying the socio-economic status of people, it is difficult to acquire such data from either official sources or on-site surveys in China. Therefore, the study relies on other available indicators from official census and open-access data of commercial companies and academic institutions.

3.2.1. Direct Indicators

The first less advantaged group in China is related to the *Hu Kou* designation. The system requires each Chinese citizen to be registered as either rural or urban based on given their location (Y. Song, 2015), which significantly affects many aspects of urban life in China (Chan, 2009). Non-locally registered residents (*Fei Ben Di Hu Kou*) are considered more vulnerable since they cannot access multiple types of urban welfare systems, including affordable housing and education (Solinger, 2016). Even more, rural migrants in urban areas often confront *Hu Kou*-based labor market discrimination, especially by high-wage state-owned companies (Y. Song, 2015). This makes rural migrants more likely to work in lower-paying jobs in urban areas (Solinger, 2016).

Housing conditions can be another useful alternative direct indicator given its direct relationship to income level as well as other social status factors. Studies have also found that income level has a great influence on housing and residential community choice in urban China (Tao, Hui, Wong, & Chen, 2015). Thus, housing areas, types,

qualities, and ownership can also indicate economic status. It is common that the wealthier can afford to purchase more expensive commercial housing with larger, higher-quality living areas. Other demographic characteristics, including age, educational level, marriage status, and unemployment rate are also reference indicators for different social groups, thus involved in this study.

3.2.2. Indirect Indicators

In addition to the above mentioned, more indicators were applied to signal the different socio-economic conditions of neighborhoods indirectly, such as published media materials, google street view, the number of chain shops, housing sales transactions, and mortgage lending information (Barton, 2014; Yasumoto et al., 2014; Zheng & Kahn, 2013). The use of non-census or open source data could be useful in regions like China where the official census data is not highly accessible to the public and is of lower resolution. The study then adds commercial housing sales prices as a proxy to discern the changes of socio-economic status especially related with green space-associated gentrification.

This is because studies on the effect of changing status of neighborhood or gentrification often combine multiple indicators to avoid over-simplification (Anguelovski et al., 2017; Bostic & Martin, 2016). The changes in economic status and demographic structure data cannot fully explain the causal relationship between increase of urban green space and gentrification. As a common indicator, housing sales prices were adopted in many studies to better observe green space-associated gentrification (Anguelovski et al., 2017; Yasumoto et al., 2014; Zheng & Kahn, 2013). By investigating

changes in the structural patterns of housing prices due to green space changes, the mediation effect of green space can be found to signal gentrification effect.

There are several reasons why housing sales can be an indicator for green gentrification. In urban China, the green gentrification effect comes in two forms. One is associated with green space associated with the “city beautification” movement that renovates dilapidated environments in city centers. These reforestation projects tend to improve the environmental quality of existing neighborhoods, which is often reflected in housing costs (Kong et al., 2007). The second effect concerns the relocation of original residents due to the installation of new green spaces. Urban reforestation projects in the urban outskirts tend to acquire large areas for installation due to the low cost of agricultural or village lands. Villages providing low cost rental housing will be replaced by more expensive commercial residential quarters that are not affordable to the poor—typically those who live in rented properties. The increase in housing costs dislocates those less wealthy groups, often forcing them into cheap and low-quality communities that might be too far away from the newly installed green spaces to benefit from the improved environment in the vicinity. Therefore, this study will use a set of longitudinal housing transaction data to monitor if newly added green spaces boost housing sales prices during urban renewal processes.

3.3. Measuring Benefits of Urban Green Space

Linked or bundled indicators are often used to measure the ecosystem benefits of urban green spaces (Dagmar Haase et al., 2014). These indicators are defined as a measure or metric based on verifiable data that conveys information about more than itself (Dagmar Haase et al., 2014). There are two main types of indicators: state and performance indicators (Lead et al., 2010). State indicators include the components or processes providing the services, such as the area of different landscapes including road, vegetation, and waterbodies, as well as the number and types of facilities, and finally the levels of biodiversity within the green spaces (Lead et al., 2010). Most research use multiple state indicators to measure the capacity of services. But state indicators do not consider human needs nor the external factors that might influence its delivery; instead, they objectively describe the single or combined physical or nonphysical environmental outputs. State indicators can be directly measured based on the various features of green space itself or be indirectly transferred to marketable observations, such as adopting the hedonic pricing model or people's willingness to pay method. Performance or consumption indicators consider how well the benefits of green space can be delivered to potential users, as well as the external physical or non-physical factors that might affect the performance (Lead et al., 2010).

Single indicators cannot reveal the complexity of ecosystem services or benefits nor the exposure of users to such benefits. In many cases, researchers combine multiple indicators or integrated methods based on the complexity or scope of the research. The accessibility index has the capacity to link together both the status of green space benefits and the delivery of such benefits, and is thus applied in this study.

3.3.1. What is Accessibility?

Accessibility issues are frequently used as part of measures aimed at increasing social welfare, often in conjunction with access to educational and health services, as well as public access to open spaces (Rowe, 2012). Accessibility affords this research the capacity to appropriately examine the how well the benefits of green space serve its users spatially, which is often integrated with the different features of green spaces as well as several geo-demographical factors. Literature on accessibility has been around since the 1950s, particularly in fields such as transportation, urban planning, and economic geography (Sevtsuk, 2010), but there is no universally-agreed upon definition of accessibility, and likewise there is no common measuring approach regarding different research focuses. Studies using accessibility as a measure for urban green spaces often adopt a combination of different approaches, given the complexity of urban conditions and the wide variety of data sets available. Before identifying the access to urban green space among different groups in this study, it is necessary to understand how measurement methodologies affect our conceptions of accessibility (Neutens, Schwanen, Witlox, & De Maeyer, 2010). The following is a brief review of the current measurement methods used to assess levels of accessibility to green spaces, as well as the limitations of such methodologies:

3.3.1.1. Container Approach

This approach calculates the number or total area of urban green spaces within an administrative or census unit (Dony, Delmelle, & Delmelle, 2015; X. Zhang, Lu, & Holt, 2011). This method is criticized because of the “edge effect” (Talen, 2013), which does not consider the accessibility of green spaces out of a census unit. In the real world, people are not constrained by census borders and can access the green spaces in adjacent

areas. Another concern is the Modifiable Areal Unit Problem (MAUP) which is related to the scale of areal unit.

3.3.1.2. Coverage Approach

Derived from the container approach, the coverage approach generates buffer zones (Nicholls, 2001), sometimes based on existing road network data from a given public amenity or park, in order to count the population with the buffer area from a given green space (Dony et al., 2015; Kabisch, Strohbach, Haase, & Kronenberg, 2016). Determining the buffer threshold is challenging and needs to be scrutinized based on different site contexts, and includes factors such as topology, traffic congestion, and climate.

3.3.1.3. Time-cost approach

The time-cost approach calculates the closest green space from population locations (X. Zhang et al., 2011). Selecting the closest green space does not always reflect reality, as people might choose further green spaces. Variations are invented to calculate potential numbers or areas of green spaces within a given Euclidean or network-based catchment zone (sometimes accounting for distance decay effects or features such as the congestion levels of parks) from populated locations to mitigate the bias (Jiao & Liu, 2010; Wei, 2017; Xiao et al., 2017).

3.3.1.4. Gravity index

The formulation of the gravity index was first introduced by Weber and Friedrich in the 1930s (Weber, 1957), and was further applied in land use location choice (W. G. Hansen, 1959). The gravity model measures distance and friction as well as the level of attractiveness of a potential destination, making it more powerful in examining potential access to green space. Since green spaces have different qualities and features, this can be

reflected in their attractiveness level as a destination. There are many variations regarding different research questions. Following the basic gravity model formulation, most research will incorporate various features of green spaces describing the attractiveness levels such as size, noise reduction capacity, air quality, facility, visitor congestion levels, and the overall quality of the green spaces (Dony et al., 2015; Fan et al., 2017; Higgs, Fry, & Langford, 2012; Jiao & Liu, 2010).

Some scholars argue that place-based measurements of accessibility like the gravity model exclude people's perception that might affect access to green spaces (Jim & Shan, 2013; Park, 2016). However, this dissertation focuses on physical aspects when measuring access to green space given the extreme complexity and efforts needed to obtain individuals' perceptions across the entire city.

3.3.2. Approach for Measuring Accessibility in This Dissertation

To measure the different benefits of green spaces, this study uses two accessibility measurement approaches. One is the Gravity Model based index for measuring the recreational benefits of public green spaces, which takes account of the varying features of green spaces and their distances. For measuring the regulating benefits of things such as air purification, cooling effects, and more, a container approach is adopted.

Baseline model of Gravity Model based accessibility index:

$$GA[i]^r = \sum_{j=1}^n \frac{F_j}{e^{\beta \cdot d[i,j]} P_i}$$

for $d[i, j] \leq r$

where

$GA[i]^r$: Gravity Model based accessibility of populated unit i .

F_j : the features such as vegetation quality, size, or facility of public green space j .

β : an exponential value for adjusting the effect of distance decay.

$d[i, j]$: distance between community i and the public green space j .

r : the search radius.

P_i : the population of a unit i .

Baseline model of container approach

$$CA[i] = \frac{F_i}{A_i P_i}$$

where

$CA[i]$: Container Approach based accessibility of populated unit i .

F_i : the features such as vegetation quality, or total size of all vegetations with in a census unit i .

A_i : area of a census unit i .

P_i : the population of a census unit i .

The model specifications for each research of the questions are further explained in the “Data and Methods” of each section (Section 4, 5, and 6).

3.4. Analytical Methods

In order to detect the relationships between access to urban green spaces and the socio-economic status of people, empirical studies utilize spatial or aspatial statistical analytical methods, including bivariate correlation, multivariate regression, local cluster analysis, and the Mann-Whitney U test. The following is a brief introduction to these methods. Specifications for each of the research questions are further explained in the “Data and Methods” of each section (Section 4, 5, and 6).

3.4.1. Multivariate Regression

Studies often rely on aspatial and spatial multi-regressions as a common approach for identifying the global and local relationships between factors of socio-economic status and access to urban green spaces (Anguelovski et al., 2017; Dai, 2011; Tooke et al., 2010; Troy, Morgan Grove, & O’Neil-Dunne, 2012; Wei, 2017; You, 2016). An OLS (Ordinary Least Squares) will normally be performed at first to gain the global associations and will usually then be followed by spatial regression models, such as Geographically Weighted Regressions (GWR), in order to further explain the local variances (Fotheringham, Brunson, & Charlton, 2002). Spatial auto-correlation is possible here because the adjoining censuses might have similar levels of accessibility, and OLS models often adopt spatial lag or error specifications (Dai, 2011; You, 2016). The GWR model considers the spatial variances and can also be easily visualized in order to identify the spatial patterns of the relationships, thereby better informing planners and decision makers (Tooke et al., 2010).

The basic formats of OLS is as follow:

$$y_i = \beta_0 + \sum_{i=1}^n \beta_i x_i + \varepsilon_i$$

for i = 1, 2, 3, ..., n

Where

y : dependent variable (attributes determining socio-economic status)

β_0 : the intercept

β_i : the coefficient

x_i : independent variable (different accessibility to green spaces)

ε : error term

n : number of observations

The basic formats of GWR is as follow:

$$y_j = \beta_j(u_j, v_j) + \sum_{i=1}^n \beta_i(u_j, v_j) x_{ij} + \varepsilon_j$$

for i = 1, 2, 3, ..., n

Where

j : geolocation

u_j, v_j : coordinates for each location multiplied by the local independent variable

x_{ij}

3.4.2. Local Indicators of Spatial Association (LISA)

LISA (Local Indicators of Spatial Association) uses the Anselin Local Moran's I index to interpret spatial clustering. LISA can identify two types of clusters and two types of outliers of census units (Anselin, 1995). For example, in the study of green space accessibility, a statistically significant positive value of Local Moran's I of a census unit indicates that the neighboring census units have a similar accessibility level. If a census unit has a high accessibility score and its neighboring census units have similarly high score, there will be a high-high cluster; Similarly, if a census unit and its neighboring areas have low scores, there will be a low-low cluster. A statistically significant negative value means the surrounding units have a significantly different level of accessibility, in other words, there are a high-low or low-high spatial outliers.

Formula for LISA is:

$$I_i = \left(\frac{z_i}{\sum_i z_i^2} \right) \sum_j W_{ij} z_j$$

Where

z_i and z_j : deviation from the mean

W_{ij} : the spatial weight matrix

3.4.3. Mann-Whitney U test

The Mann-Whitney U test will be implemented to identify if a census unit with better socio-economic status is better served with urban green spaces. Following Talen's approach (Talen, 2013), this dissertation compares the socio-economic indicators of two groups of censuses. One group has high access to green spaces and the other has low

access to green spaces. Census units within the lowest quartile range of access are included in the groups with low access; similarly, those whose access to green spaces are among the highest quartile are included in the groups with high access. The test will be applied to each set of socio-economic indicators to discern if the distribution values for high and low groups are significant. This non-parametric approach can discern if there is a significant difference between the two groups of data (Ebdon, 1985).

Formula for Mann-Whitney U test is:

$$U = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - \sum_{i=n_1+1}^{n_2} R_i$$

$$z = \frac{U - m_U}{\sigma_U}$$

Where

n_i and n_j : the sample size of each group

R_i : the rank

m_U : mean of U

σ_U : standard deviation of U

3.4.4. Hedonic Pricing Model

The Hedonic Pricing Model is an economical method that can deconstruct prices of goods or services (Czembrowski & Kronenberg, 2016; Kong et al., 2007). In this study, the model is constructed to find out how much the house price is influenced by urban green spaces. By comparing patterns of transaction prices during the study period

(2011-2018), this approach can identify changes to further discern the premium effect of public green spaces before and after adding green spaces. Researchers using the hedonic pricing model often confront spatial auto-correlation issues, which might lead to inaccurate results (Basu & Thibodeau, 1998). This is because the housing sales price is influenced by neighborhood property prices (Czembrowski & Kronenberg, 2016). One way to mitigate the spatial autocorrelation is to adopt a spatial effects model.

Baseline Hedonic pricing model:

$$P_i = \beta_0 + \sum \beta_k H_{ki} + \sum \beta_l N_{li} + \sum \beta_m G_{mi} + \varepsilon_i$$

for $i = 1, 2, 3, \dots, n$

Where

P_i : the transaction price of property i

H_{ki} : the k^{th} structural characteristics of properties i

N_{li} : the l^{th} neighborhood characteristics of properties i

G_{mi} : the m^{th} green space attributes of properties i (access to public green space)

ε_i : the error terms of observation i

3.5. Data Sources and Processing

Considering that the neighborhood scale socio-economic data and official green space maps of a city is extremely hard to acquire in China, this dissertation relies on multiple sources for data collection, including those which are open-source and collected through official census, commercial mapping and real estate companies, and academic institutions. All of the collected data sets have gone through a manual check processing by the author according to the high-resolution satellite images, gazetteer, published yearbooks, and official maps in guarantee the accuracy.

3.5.1. Urban Green Spaces

The extraction and determination of urban green spaces relies on multiple sources including official census maps, urban planning documentations, commercial guiding map providers, high resolution aerial photos, and remote sensing satellite images. The number of parks and their respective geolocations comes from the Beijing Municipal Bureau of Greening and Gardening (Capital Greening Office). As of 2017, there are a total of 315 registered park green spaces within 5km from the six subdistricts in Beijing (Capital Greening Office, 2018). Including those beyond 10km from the border of the subdistricts is to eliminate the edge effect when measuring accessibility. The border and built year of a given park's green spaces are identified based on historical satellite maps acquired from Google Earth and are double checked manually with official planning maps and POI (point of interest) records from Gaode Map. All vegetation areas in the study area is extracted from opensource remote sensing images such as Landsat and Sentinel 2. The detailed data extraction and processing approaches can be found at the "Data and Methods" in Section 4, 5, and 6.

3.5.2. Indicators for Different Socio-economic Groups

3.5.2.1. Official Census Data

The official census data comes from the national demographical census in 2000 and 2010. Those before the year 2000 are excluded from the study because the statistical bureau used different statistical calibers and thus cannot be used to conduct a longitudinal study. The smallest tract unit of official census data is the Township level (*Jie Dao* in urban areas; *Qu or Xian* in rural/suburban areas).

The following indicators from census data are used for determining socio-economic groups:

- Unemployment rate (%)
- Population with non-local *Hu Kou* (%)
- Population with bachelor or higher degree (%)
- Population who live in an owned property (%)
- Average housing area per capita (m²)

3.5.2.2. Residential Community Information (*Ju Zhu Xiao Qu*)

The census tract in China is relatively large: even the smallest census unit, *Ju Wei Hui*⁸, might contain multiple communities with different socio-economic conditions at the finer scale. In order to discern socio-spatial disparity at a finer scale, this research relies on multiple online open sources, including POI (point of interest) and AOI (area of interest) extracted from Gaode Map, which is one of the most popular commercial web

⁸ Demographical census data at *Ju Wei Hui* level is not available to the public.

mapping service companies in China. Additional socio-economic related data, such as the average area of a housing unit and the average housing price, are derived from real estate brokerage companies such as Lianjia⁹, Anjuke¹⁰, and Fangtianxia¹¹. The geolocations and borders of residential communities are extracted from Gaode Map based on the Application Programming Interface (API), and are further manually checked and adjusted based on high-resolution satellite and street images from Gaode. Communities without enough geographical information and borders which are hard to identify are excluded from the study.

3.5.2.3. Housing Transaction Data

The commercial housing market has entered a “second-hand housing era” in 2010 when more resold houses exceeded newly developed properties. The rapid growth of the second-hand housing market and private brokerage industry accumulated large numbers of detailed transaction data across the entire built-up area of Beijing and are available through their websites. Thus, second-hand commercial housing sales will be a feasible index supplementing socio-economic status of people and be further used to identify the dislocation and gentrification effects at a city scale.

The housing transaction data involved in this study is extracted from one of the largest brokerage companies: Lianjia¹². The company provides valid open source data of real transactions of resold commercial housing property with detailed structural features. The author has extracted and processed the data from the years 2011 to 2018 and

⁹ <https://bj.lianjia.com/>

¹⁰ <https://beijing.anjuke.com/>

¹¹ <https://bj.fang.com/>

¹² The source of data: <http://bj.lianjia.com/chengjiao>

georeferenced each property's location. The housing data set only uses commercial housing which has a seventy-year property right excluding affordable, state-owned, and collective-owned properties. All the housing properties involved have a lease year limitation of seventy years, indicating they are built on land with a residential zoning code. Those with a lease year limitation of forty or fifty are built on industrial or commercial land use zones but sold as residential or residential/commercial housing which has a much lower sales prices and thus is excluded from this study. Housing properties that have an area of less than 5 square meters, and/or are in a basement are removed from our data set. Those with insufficient structural variables are also excluded. The structural information includes the number of bedrooms, living rooms, kitchens, and bathrooms, installation of elevation, heating condition, interior decoration, and building age.

3.6. Summary of Data and Methods Used in This Dissertation

Major Research Questions	Urban Green Spaces	Socio-economic Groups	Analytical Methods	Major Data Sources
1) How are urban green spaces distributed among socio-economic groups? (cross sectional study in 2017)	-Public green spaces -All types of vegetation	Residential Communities: -Avg housing price -Avg housing unit area -Hukou -Education - Unemployment -Property ownership	-OLS -GWR -LISA - Mann-Whitney U test	-Gaode Map -Google Map -Remote sensing map (Sentinel 2) by ESA -China official census 2010 -Lianjia housing transaction data (2011-2018)
2) Are urban green spaces more often provided to advantaged socio-economic groups? (longitudinal study 2000-2010)	-Public green spaces -All types of vegetation	Official Census tract -Hukou -Education - Unemployment -Avg housing area per capita	-OLS -GWR	-Gaode Map -Google Map -China official census data in 2000 and 2010 -Landsat 8 by NASA
3) Does adding green space dislocate less advantage groups by gentrification? (longitudinal study 2011-2018)	-Public green spaces with different types and features	Housing Price	Hedonic Pricing Model with Difference-in-Difference estimator	-Lianjia housing transaction data (2011-2018) -Gaode Map -Google Map

4. The Distributional Pattern

This section examines the spatial pattern of socio-economic groups *vis-à-vis* the distributional pattern of their access to urban green space by answering the following questions:

- How are urban green spaces with different features and benefits distributed among social groups in residential communities in Beijing?
- Does provision of urban green spaces more favor advantaged socio-economic groups?
- If so, what are the attributes of these urban green spaces and possible explanation?

4.1. Introduction

Understanding the spatial pattern of how different socio-economic groups access public green space is the first step to addressing social inequality. This section uses individual residential communities to identify the socio-economic pattern of the city and examine how it matches or mismatch urban green space accessibility.

Existing studies construe urban green space in an overly broadly manner. A majority of the studies define urban green space as a uniform amenity focusing individual feature such as size. Green spaces with different sizes, shapes, types, features, and quality of maintenance exert varying levels of benefit and service to users (Forman, 2014; L. Xu et al., 2016). The contextual geographical and demographical factors of urban communities might also influence use-patterns. Without considering these aspects, the precedent studies are of limited use to planners and decision makers.

Additionally, most research on Chinese cities relies on official census data, such as that of subdistrict (*Jie Dao*) or neighborhood community data (*Ju Wei Hui*) as a proxy to define social groups (Wei, 2017; Xiao et al., 2017; You, 2016). However, the census tract in China is relatively large, and so even the smallest unit, *Ju Wei Hui*, might contain multiple communities with different socio-economic conditions at the finer scale. Studies relying on large census tract data have difficulty reflecting the spatial distribution at these finer-grained scales, which can negatively impact urban planning. Even worse, such scale issues might generate biased outcomes.

4.2. Data and Methods

The study area focuses on the built-up area of the six central subdistricts in Beijing—*Dong Cheng, Xi Cheng, Hai Dian, Chao Yang, Shi Jing Shan, and Feng Tai*, which are located mostly within the fifth ring road (see Figure 4-1 & Figure 4-2). In 2017, the total population of entire city including all subdistrict is 21,707,000, and the six central districts have 12,088,000 sharing 55.7% of the total population (Beijing Bureau of Statistics, 2017). The area of six central subdistrict is 1,381 square kilometers (Beijing Bureau of Statistics, 2017).

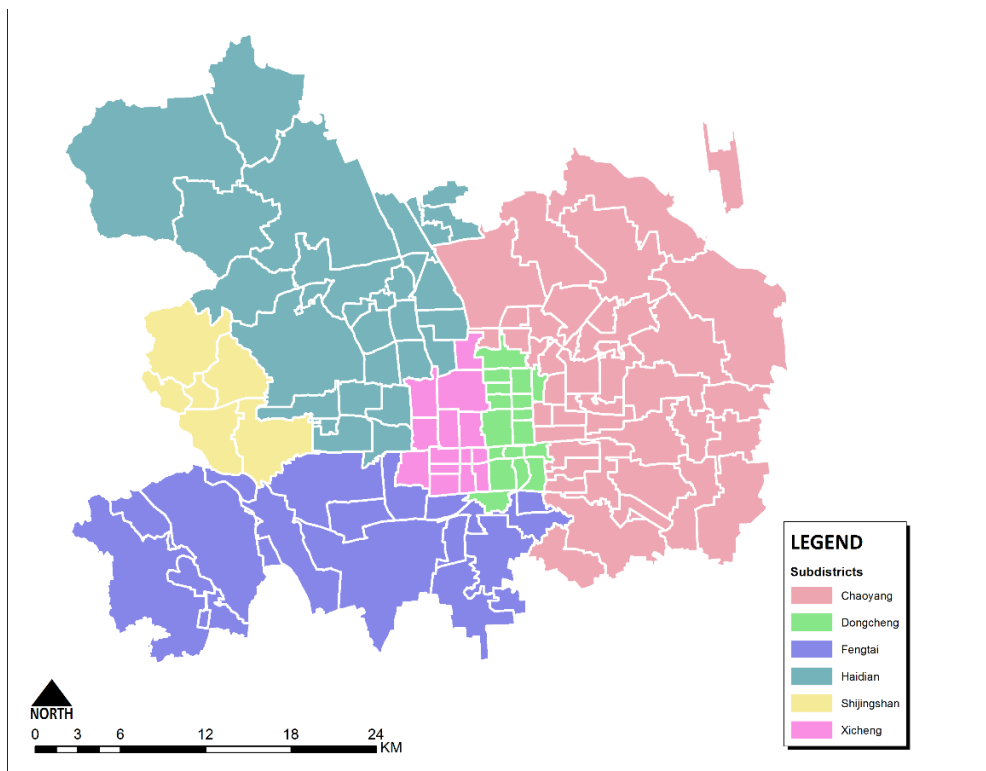


Figure 4-1 The study area and the townships in Beijing. Author drawn based on administrative map of Beijing 2014.

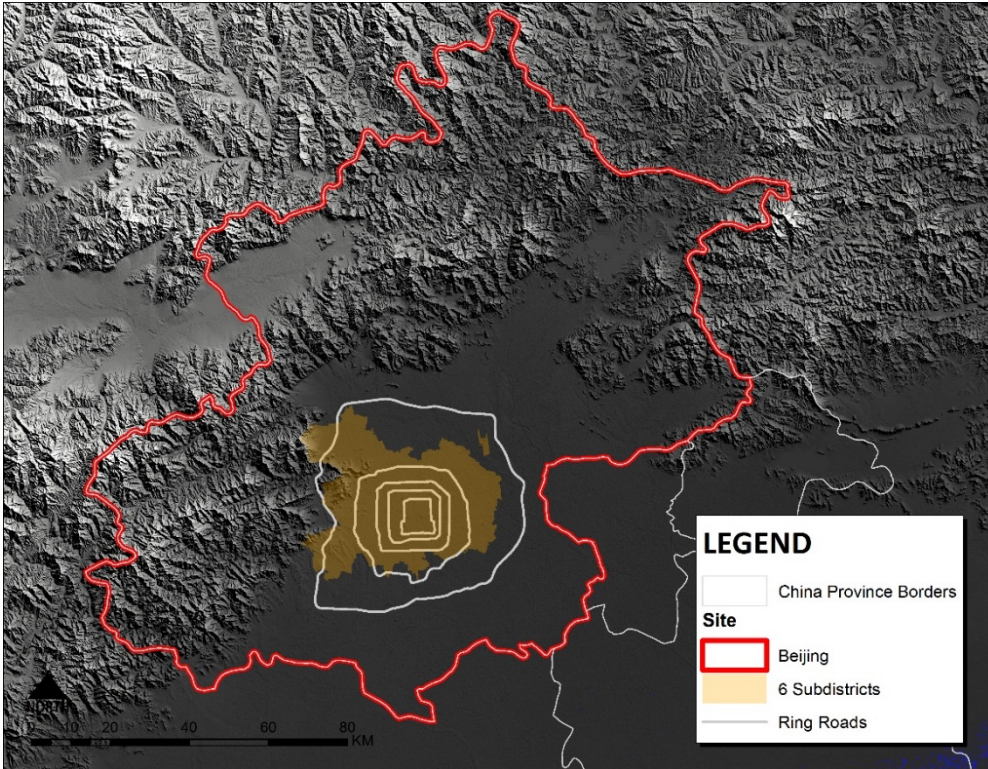


Figure 4-2 Topography and administrative border. Author drawn based on NASA 2019 and administrative map of Beijing 2014.

4.2.1. Data of Indicating Socio-economic Groups

In order to discern socio-spatial disparity at a finer scale, this dissertation relies on the residential community as a basic unit for identifying the socio-economic groups in Beijing. Multiple online and open access sources—such as POI (point of interest) and AOI (area of interest)—are extracted from Gaode Map, one of the most popular commercial web mapping service companies in China, as well as georeferenced real housing transaction data from Lianjia—the largest real estate brokerage company in China. A total number of 2643 residential communities are extracted and georeferenced, accounting for more than 50 % of total residential communities 5346 in the six districts in Beijing (see Figure 4-5). The residential communities are mostly gated are similar to the gated communities in the West through their emphasis on restricting public access

(Blakely & Snyder, 1997). Public amenities that are in these communities (see Figure 4-3), such as recreational facilities, green space, or daycare centers, are only accessible for their owners and/or residents and are maintained by property-owner committees or private third-party management companies (F. Wu, 2005). Non-residential communities—such as military attached housing, commercial offices converted apartments, university campus, and hotels—are excluded, since their socio-economic data is not available. The population of each residential community is calculated by multiplying the total number of units and average number of persons in a household in the census tract of the community. All 2643 residential communities involved in this dissertation are built before 2010 (see Figure 4-4).



Figure 4-3 Inner green space and other amenities in a gated community.

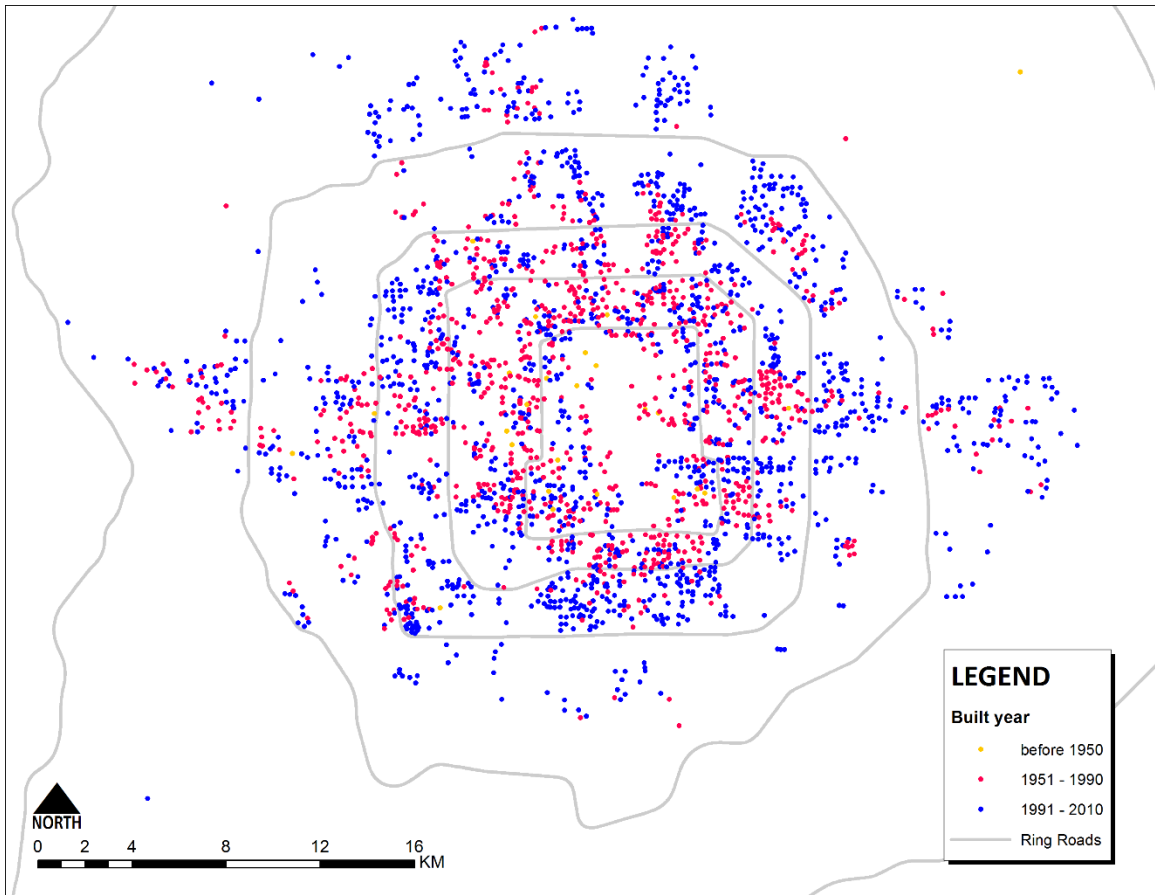


Figure 4-4 Built year of residential communities in Beijing (sample used in this study). Author drawn based on Gaode Map 2017 and Lianjia 2018.

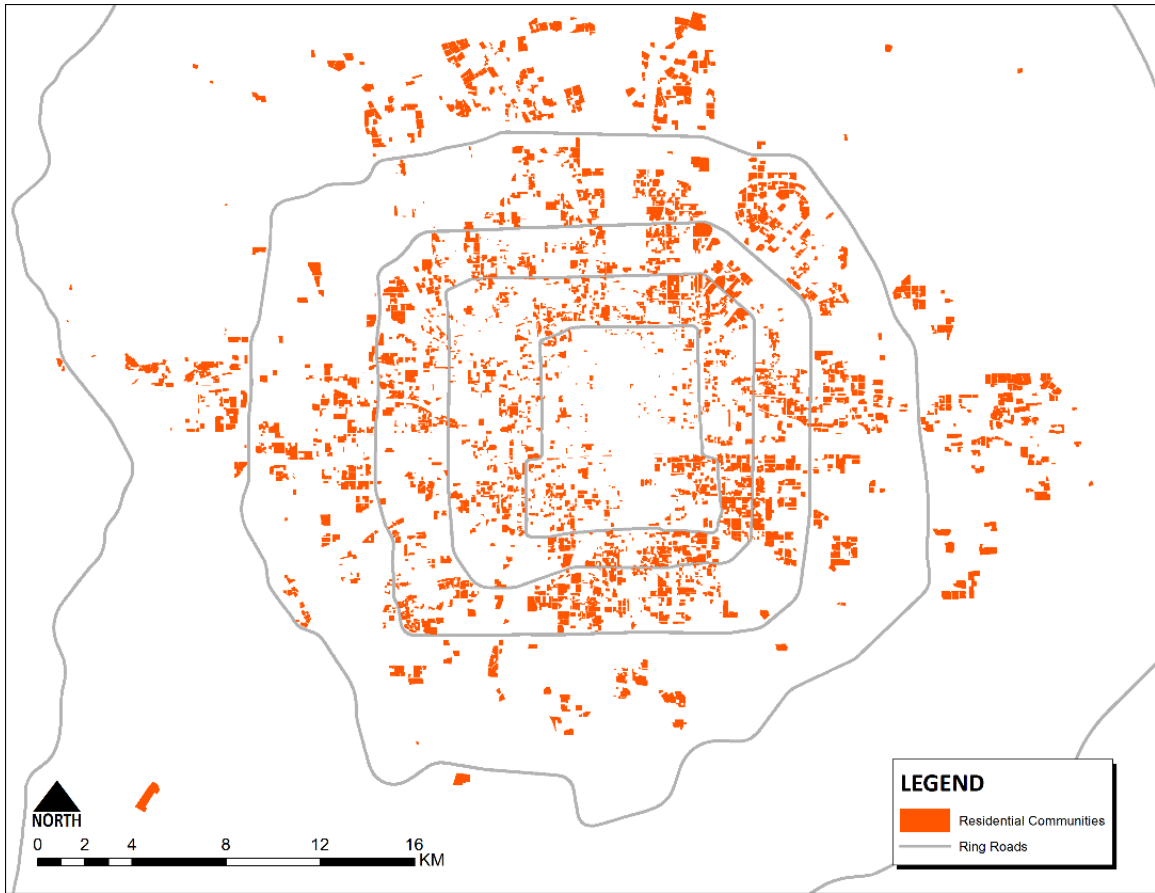


Figure 4-5 Distribution of residential communities in Beijing (sample used in this study). Author drawn based on Gaode Map 2017.

Each residential community is assigned six socio-economic indicators:

- 1) Average housing transaction price per square meter (Unit: CNY)¹³
- 2) Average housing unit area based on real housing transaction data (Unit: Square Meter)¹⁴
- 3) Unemployment rate (Unit: Percentage)¹⁵

¹³ Real estate brokerage company Lianjia commercial housing transaction data 2016. (<https://bj.lianjia.com/>)

¹⁴ Real estate brokerage company Lianjia commercial housing transaction data 2011-2017. (<https://bj.lianjia.com/>)

¹⁵ National official census 2010 at township level in Beijing

- 4) Population with non-local *Hu Kou* (Unit: Percentage)¹⁶
- 5) Population with bachelor or higher degree (Unit: Percentage)¹⁷
- 6) Population who live in an owned property (Unit: Percentage)¹⁸

The first two indicators are based on housing transaction data from one of the largest housing brokerage companies in China: Lianjia. The latter four come from the National Statistical Census of 2010 (at the Township level) and were spatially joined with each residential community. Each indicator is then reclassified into four levels in the ArcGIS 10.6.1 (ESRI) platform using a quantile classification approach (see Figure 4-6 & Figure 4-7 Figure 4-8 Figure 4-9 Figure 4-10 & Figure 4-11). The higher rank number shaded in green dots indicates the higher socio-economic status; the lower rank number shaded in red dots are the lower social class. A final map is generated by summing up the reclassified four socio-economic ranks (see Figure 4-15) and LISA¹⁹ index is calculated to present the spatial clustering (see Figure 4-16).

¹⁶ National official census 2010 at township level in Beijing

¹⁷ National official census 2010 at township level in Beijing

¹⁸ National official census 2010 at township level in Beijing

¹⁹ The LISA index is calculated at ArcGIS 10.6.1 (ESRI) platform using Inverse Distance setting for conceptualizing spatial relationships and Euclidean Distance method. Number of permutation is 499.

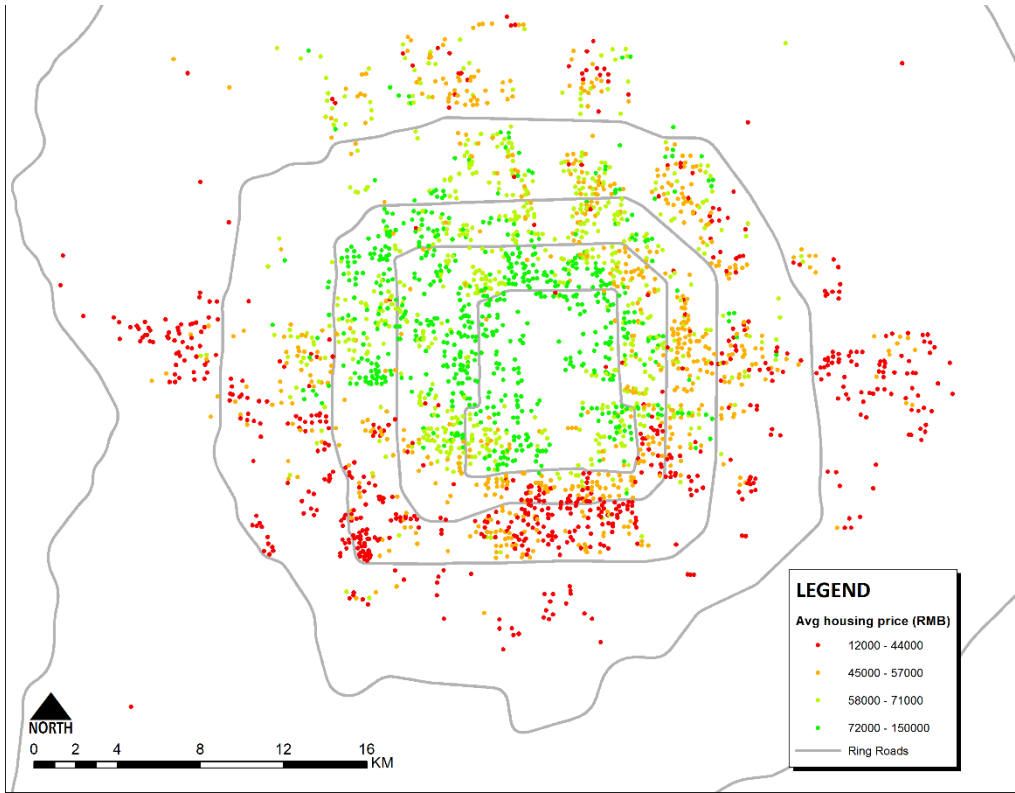


Figure 4-6 Average housing transaction price per sqm.

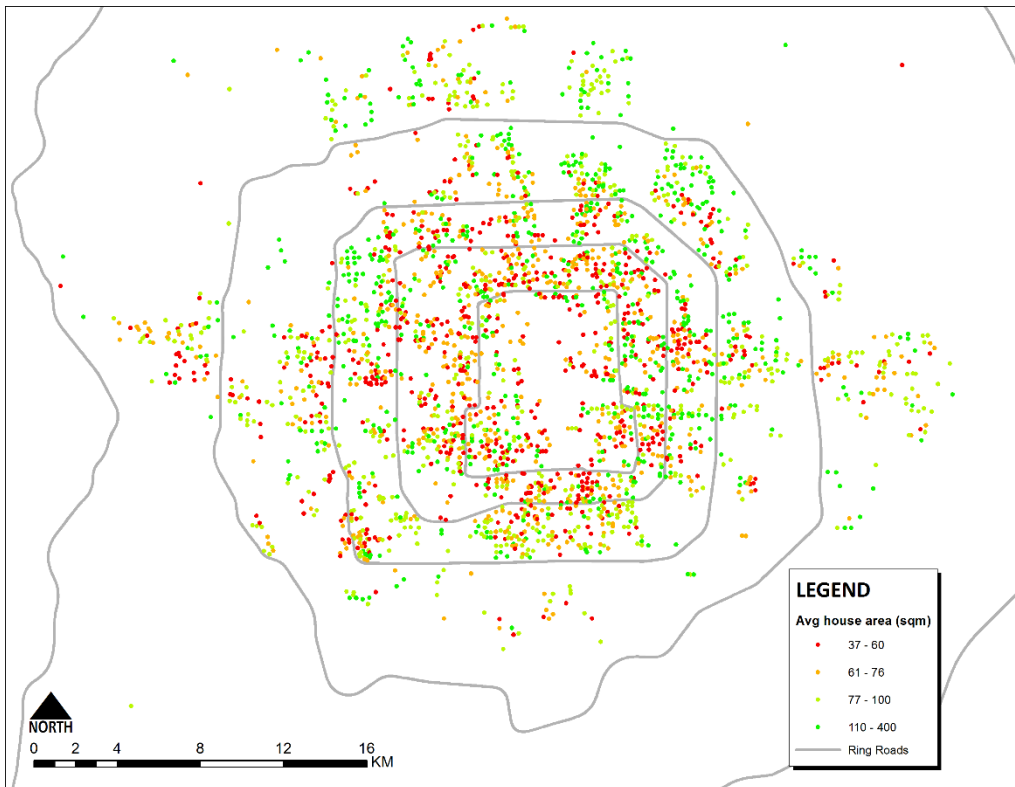


Figure 4-7 Average housing unit area in sqm.

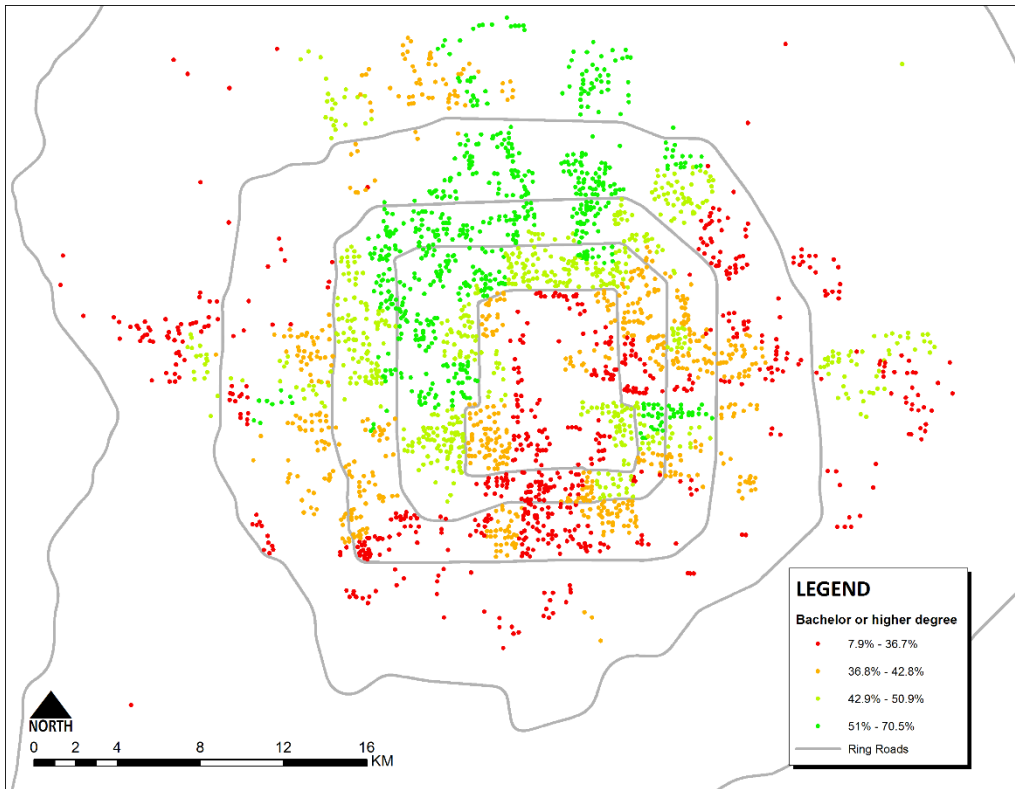


Figure 4-8 Population with bachelor or higher degree.

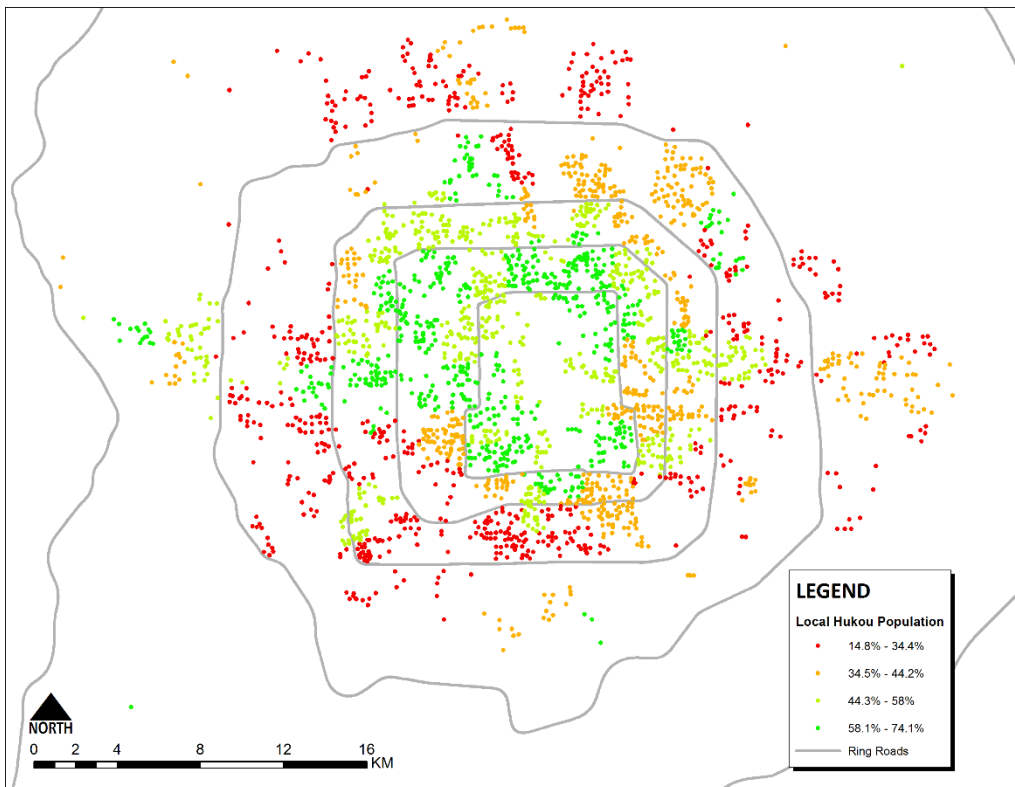


Figure 4-9 Population with local hukou.

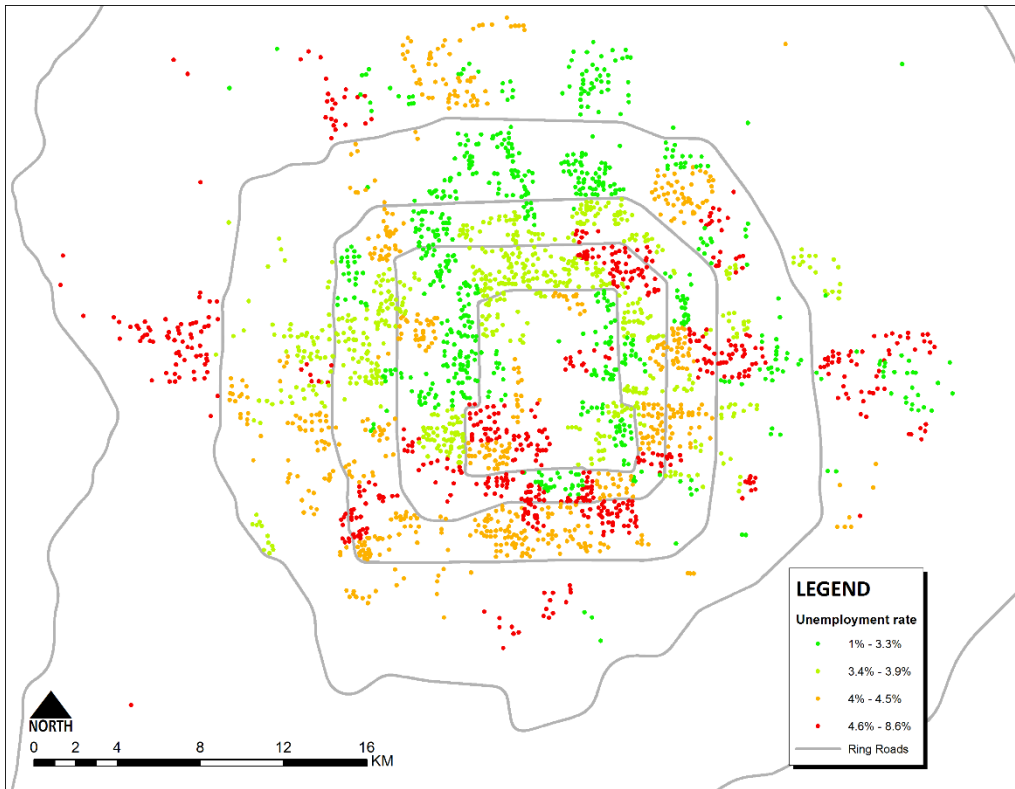


Figure 4-10 Unemployment rate.

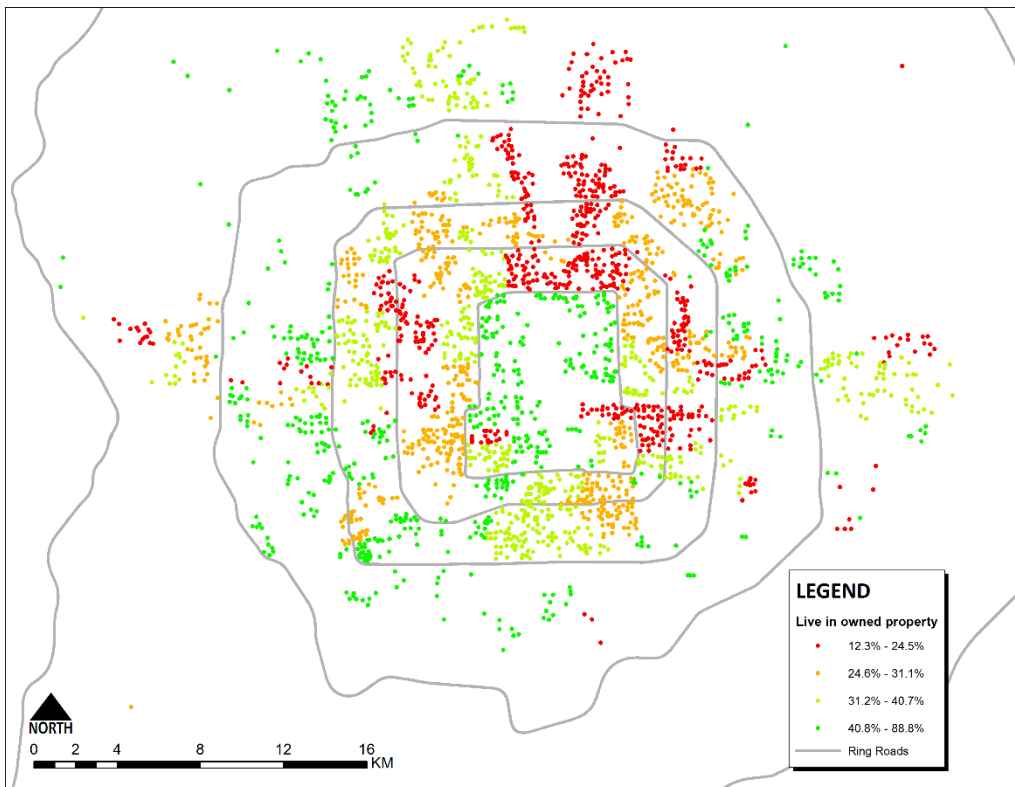


Figure 4-11 Population who live in an owned property

4.2.2. Measuring Accessibility to Urban Green Spaces

This study measures the recreational and environmental regulating benefits of green spaces given that they are major benefits afforded to residents in urban contexts (Chang et al., 2017). The number of parks and their geolocations come from the Beijing Municipal Bureau of Greening and Gardening (Capital Greening Office). There are a total 315 registered park green spaces as of the year 2017 (Capital Greening Office, 2018). The border and built year of a given park's green spaces are identified based on historical satellite maps from Google Earth (see Figure 4-12).

Two accessibility indicators are used to measure these benefits respectively (see Figure 4-13). A gravity-model-based index is used to measure the recreational benefit considering both the quality and distance to urban public green spaces (see Figure 4-17). The quality of green space is evaluated based on NDVI (Normalized Difference Vegetation Index). First, the vegetation pixels (10-meter resolution) of each public green space are extracted from remote sensing images from Sentinel 2 L1C using a general threshold of NDVI value at 0.3. Second, the average value of NDVI as quality proxy is calculated for each public green space patch following a previous study (Yao et al., 2014).

The formula of Gravity Model based accessibility is:

$$GA[i]^r = \sum_{j=1}^n \frac{Q_j S_j}{e^{\beta \cdot d[i,j]} P_i}$$

for $d[i, j] \leq r$

where

$GA[i]^r$: Gravity Model based accessibility of residential community i .

Q_j : the quality (average NDVI value) of public green space j .

S_j : the size in square meter of public green space j .

β : an exponential value for adjusting the effect of distance decay. This study used the distance decay effect β with 0.002 in meter unit, from Handy and Niemeier's study on pedestrian trips to retail facilities in Oakland, CA (Handy & Niemeier, 1997).

$d[i, j]$: a linear distance between community i and the public green space j .

r : the search radius using 1600m in this case.

P_i : the population of a residential community (*Ju Zhu Xiao Qu*).

To measure regulating benefits such as noise reduction, air purification, and micro-climate adjustment, the percentage of vegetation coverage within the border of residential community is calculated also based on the same 0.3 NDVI threshold from Sentinel 2 L1C (see Figure 4-18).

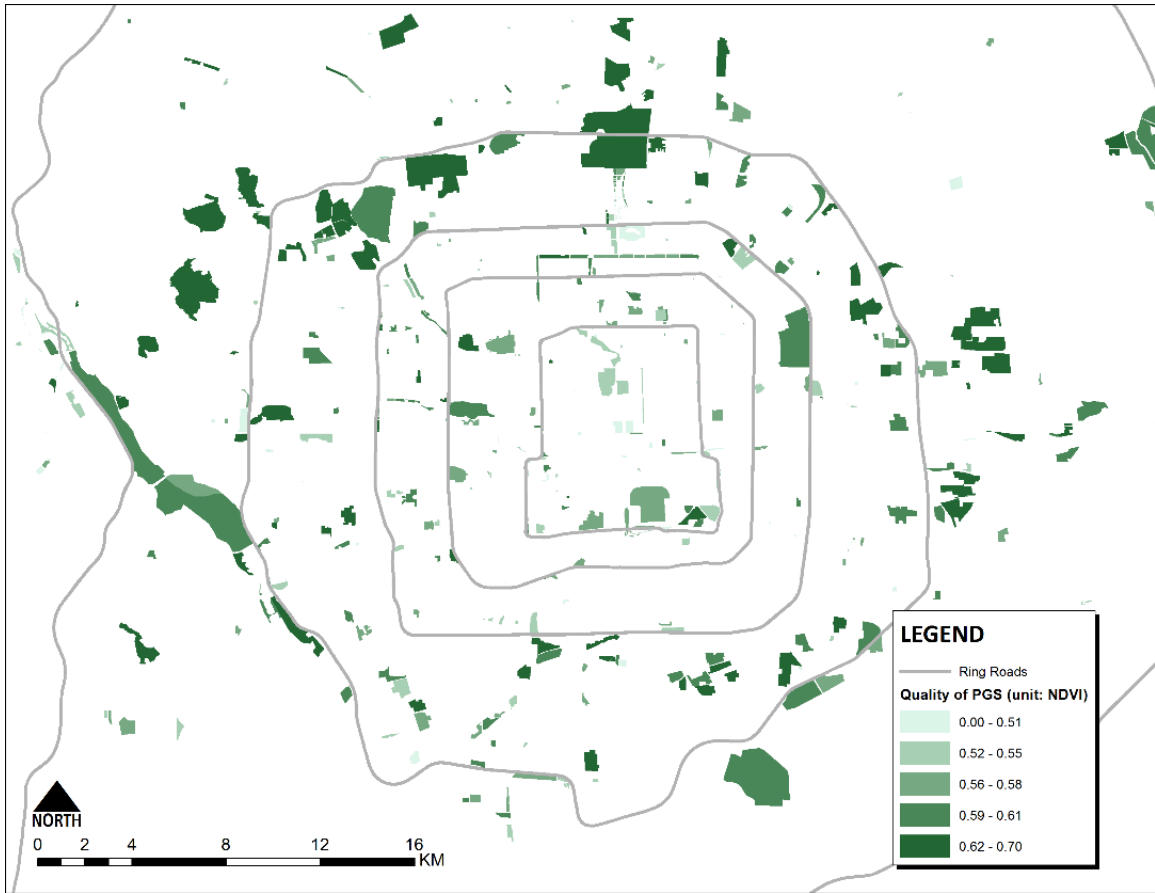


Figure 4-12 The quality and distribution of public green spaces. Author drawn based on NASA 2018, ESA 2018, and Capital Greening Office 2017.

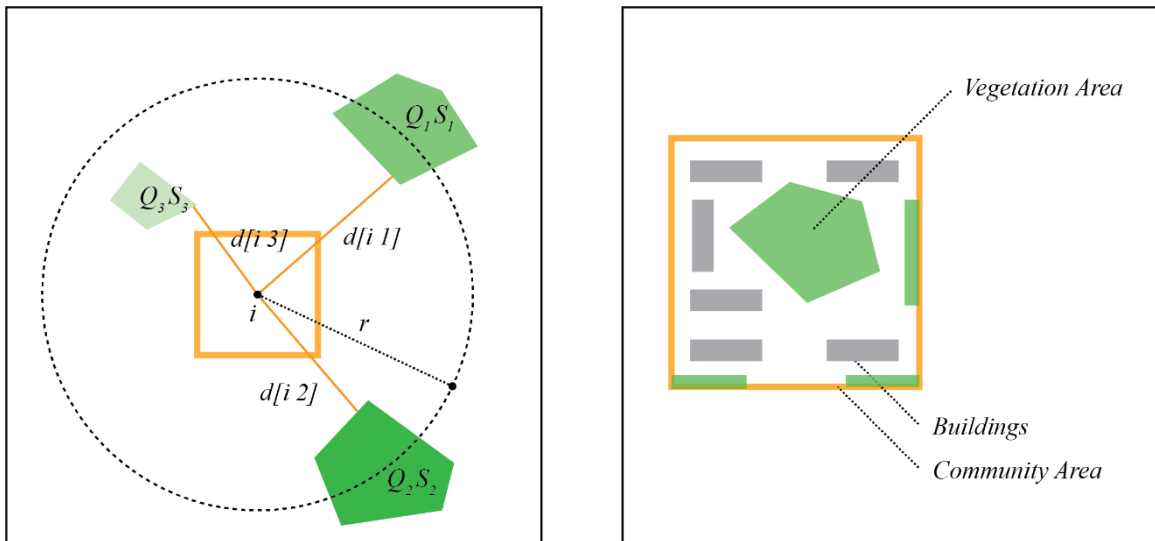


Figure 4-13 Conceptual diagram for measuring access to public green spaces (left) and internal vegetation coverage (right).

4.2.3. Analytical Methods

At first, an ordinary least squares (OLS) regression is performed to analyze the relationship between socioeconomic status and access to green spaces. Three models are used: Model 1 assumes spatial stationarity across the study area; Model 2 and 3 employ fix effect and spatial lag or error specifications respectively due to the significant spatial autocorrelations of accessing green spaces that are detected in preliminary tests.

A preliminary test shows that the Moran's I of accessibility to parks is 0.452 with a p-value < 0.001 and the Moran's I of vegetation coverage is 0.205 with a p-value < 0.001. The robust Lagrange multiplier test is conducted to determine the use of spatial lag or error specification (Lesage & Pace, 2009). In this case, the results indicate the use of spatial lag specification. See OLS diagnostic (see tables of 8.1) in the Appendix. The spatial matrix for spatial lag model employs a Queen Continuity approach. The OLS and fix effect models are conducted in Stata 15 platform. The spatial autocorrelation tests and spatial lag model are conducted in Geoda 1.14 Platform.

The formula of basic OLS is:

$$y = \beta_0 + \sum_{i=1}^n \beta_i x_i + \varepsilon$$

for $i = 1, 2, 3, \dots, n$

where

y : dependent variable (socio-economic status in this case)

β_0 : the intercept

β_i : the coefficient for independent variable x_i

ε : error term

The formula for spatial lag model is:

$$y = \alpha + \beta x + \lambda W_y + e$$

where

α : the intercept

y : the dependent variable (socio-economic status in this case)

W_y : the spatial matrix for y

β : the coefficient for independent variable x

λ : the coefficient for spatial matrix W_y

The formula for spatial error model is:

$$y = \alpha + \beta x + e \quad (e = \lambda W_e + u)$$

Where

α : the intercept

y : the dependent variable (socio-economic status in this case)

W_e : the spatial matrix for e

β : the coefficient for independent variable x

λ : the coefficient for spatial matrix W_e

Then, a Geographical Weighted Regression (GWR) is adopted to analyze spatial variance of the relations between access to urban green spaces and the socio-economic status of residential communities. Given many urban processes are spatially nonstationary in the real world, the same independent observations generate different estimations within the study area (Fotheringham et al., 2002). GWR can discern such spatial variabilities by calculating a local estimator for each location using a distance-weighting specification, which can better explain local conditions than traditional global regression methods, such as OLS (Tooke et al., 2010). Further, the results of local spatial analysis provide powerful visualization displays via multiple GIS platforms (Fotheringham et al., 2002; Tooke et al., 2010).

The formula of GWR is:

$$y_j = \beta_0(u_j, v_j) + \sum_{i=1}^n \beta_i(u_j, v_j)x_{ij} + \varepsilon_j$$

for $i = 1, 2, 3, \dots, n$

where

y_j : dependent variable (socio-economic status in this case).

$\beta_0(u_j, v_j)$: the intercept of location j .

$\beta_i(u_j, v_j)$: the local parameter estimator for independent variable x_i at location j (access to green space in this case).

u_j, v_j : coordinates for each location j .

ε_j : error term.

Each observation is weighted by using a distance decay function.

Two GWR models are adopted to explore the relationships between (1) socio-economic status of residential communities and accessibility to public green spaces, and (2) socio-economic status of residential communities and vegetation coverage in the community. The regressions are conducted via the ArcGIS 10.6.1 (ESRI). An adaptive kernel bandwidth is set to obtain the optimal number of neighbors due to the widely disparate distances of observations in this study. Corrected Akaike information criterion (AICc) is used to determine the optimal value of bandwidth (Fotheringham et al., 2002).

Table 4-1 Statistical descriptions of variables

Variables	N	Mean	S.D.	Min	Max
Socio-economic level	2,602	14.95	3.734	6	24
Coverage of vegetation	2,602	0.345	0.164	0	0.883
Accessibility to parks	2,602	0.011	0.033	0	0.615

Note: 41 observations are removed due to lack of sufficient data

The Mann-Whitney U test is implemented to identify if a residential community with better socio-economic status is better served with urban green spaces. Following Talen’s approach (Talen, 2013), this section compares the socio-economic indicators of two groups of censuses. One group has high access to green spaces and the other has low access to green spaces. Residential communities within the lowest quartile range of access are included in the groups with low access; similarly, those whose access to green spaces are among the highest quartile are included in the groups with high access. The

test will be applied to the socio-economic rank to discern if the distribution values for high and low groups are significant. This non-parametric approach can discern if there is a significant difference between the two groups of data (Ebdon, 1985). The test is conducted by using Stata 15 platform.

Formula for Mann-Whitney U test is:

$$U = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - \sum_{i=n_1+1}^{n_2} R_i$$

$$z = \frac{U - m_U}{\sigma_U}$$

Where

n_1 and n_2 : the sample size of each group

R_i : the rank

m_U : mean of U

σ_U : standard deviation of U

4.2.4. Visualization Approaches

In order to display the spatial pattern of the most abnormal cases, scenario-based mapping approaches are used according to previous literature (Tooke et al., 2010). The first step is to identify better explainable observations using mean local adjusted R-square as a threshold. Selected observations with adjusted local R-square higher than the mean value are reclassified into two groups based on the direction of associations. Then, observations that are within the highest or lowest quartile ranks of accessibility to urban

green spaces and socio-economic status are selected and shaded on the map (see Figure 4-14). The method can deliver the strength, direction, and location of observed relationships of abnormal cases for further site-specific planning and policy interventions.

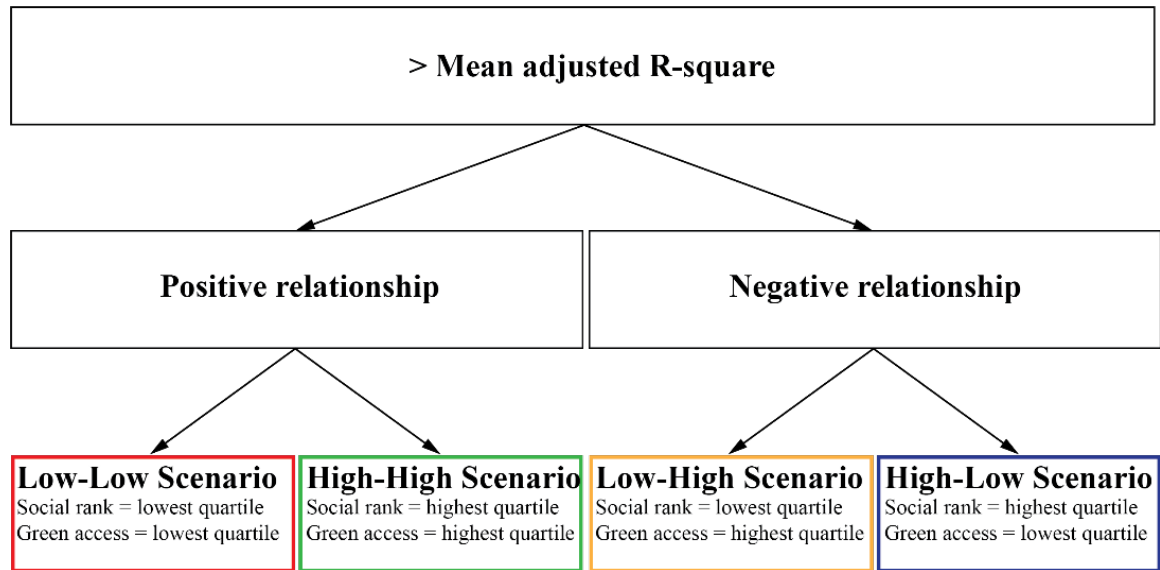


Figure 4-14 GWR results mapping approach. Author drawn based on Tooke et al.

4.3. Results

4.3.1. Spatial Distribution of Socio-Economic Status and Green Space Accessibility

The socio-economic status of a given residential community represents a distinct “North-South” difference. Advantaged groups are largely concentrated in the northwest between the 2nd and 5th ring roads and southeast corner within the center of the old city, bordered by 2nd ring road (see Figure 4-15). Marginalized peoples mostly live in the southeastern areas, between the 2nd and 5th ring roads, though some live in the north and west part beyond the 4th ring road. A further shaded map of LISA (local indicator of spatial autocorrelation) statistically confirmed such clustering of different social groups (see Figure 4-16). The spatial pattern of different social groups is the descendant of the historical layout of the ancient capital where the north and northeast were dedicated to royal gardens and palaces for empire families. This pattern experienced only minor intervention during the years of war and conflict that took place after the termination the *Qing* dynasty, and was further reinforced by the initial urban master plans of the new China. Since the 1950s, the master plan of Beijing designated the northwestern areas as educational zones including famous gardens such as the Summer Palace, and the central area of the old city (within 2nd ring road) was to be for use by the central government (Beijing City Planning Commission, 1958). The southern parts of Beijing were designated for heavy industries and affiliated infrastructures, including railways (Beijing City Planning Commission, 1958). This socio-spatial structure continued to expand as the city has grown into the suburban areas of today.

Accessibility levels of urban public green spaces show a “wedged” pattern (see Figure 4-17), which is largely the result of the urban green space network proposed in the

recent green space planning (Beijing Municipal Institute of City Planning and Design, 2007). The public green spaces within the central city remained relatively intact throughout the city's history, though. The peripheral green spaces previously served as largely agricultural lands and affiliated forest patches were dispersed among heavy industrial lands in the first urban master plans, which served as the basis for "Green Belt" that was proposed to control urban sprawl. However, the "Green Belt" was considered a failure and was eventually displaced by intensive real estate development (Ma & Jin, 2019). Subsequent plans then adopted a "wedged pattern" for connecting the fragmented patches—most of which were turned into countryside parks—with infrastructure applied linear green corridors.

The internal vegetation coverage of residential communities—indicating the regulating benefits—presents a relatively clear pattern through which the residential communities inside the 3rd ring road have a lower degree of internal vegetation coverage than those "outside," located between the 3rd and 5th ring roads (see Figure 4-18). It is because the peripheral residential communities were more recently built that they better incorporate internal green spaces, especially when compared with those old neighborhoods such as heavily densified *Hu Tong* and *Dan Wei* affiliated residential quarters close to the city center.

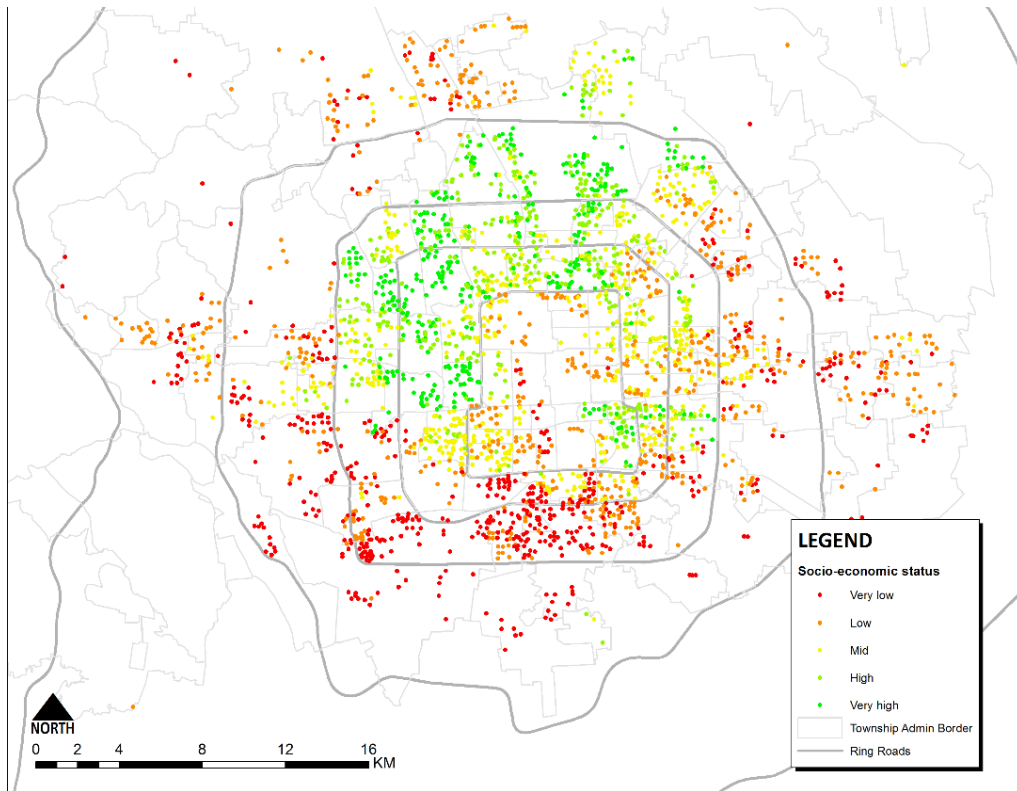


Figure 4-15 Rank of Socioeconomic status (high shaded as green; low shaded as red).

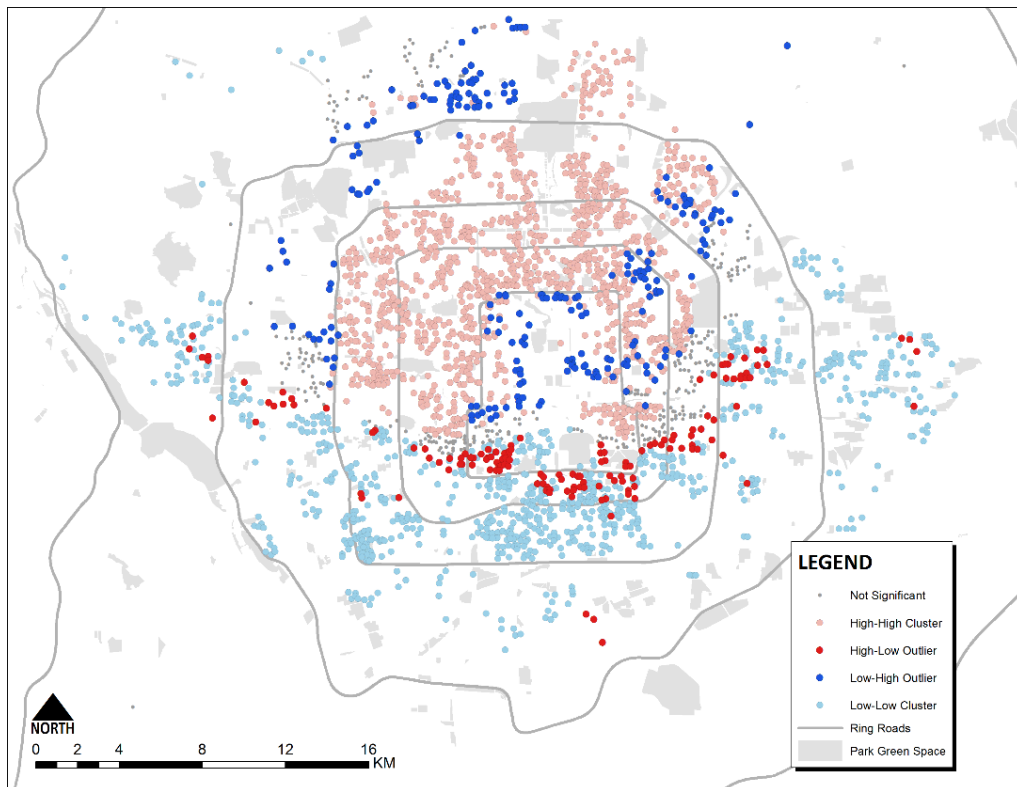


Figure 4-16 Anselin Local Moran's I index.

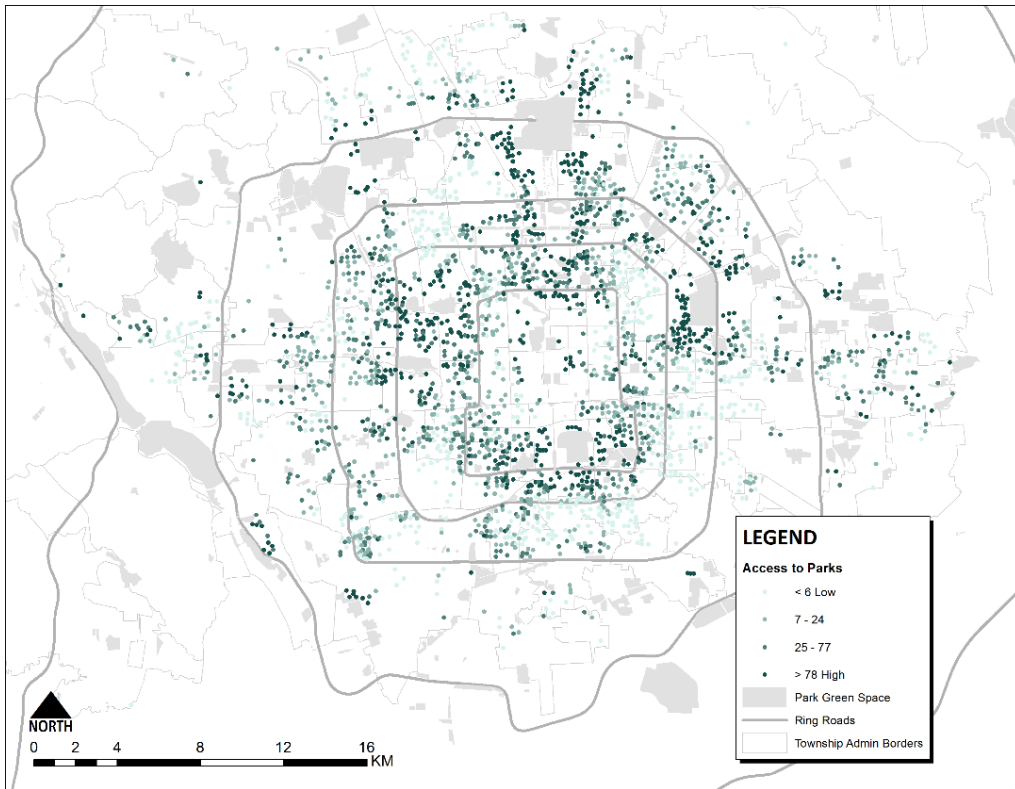


Figure 4-17 Accessibility to public green spaces at residential community level.

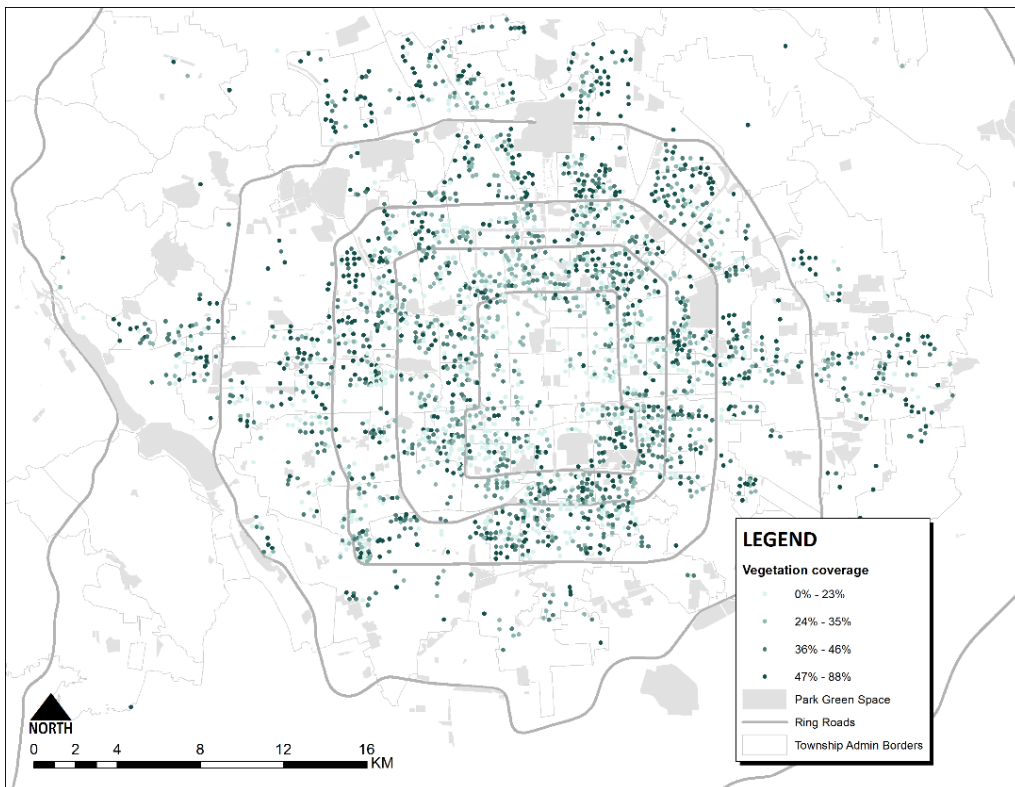


Figure 4-18 Vegetation coverage ratio at residential community level.

4.3.2. Spatial Disparity of Associations Between Green Space Accessibility and Socio-Economic Status

The global regressions indicate the public green spaces tend to better serve the marginalized groups than the internal collectively owned green spaces. The regression results reveal a statistically significant outcome that residential communities with higher access to parks are ranked lower in terms of socio-economic status in the spatial lag model (Model 3 in Table 4-2). On the contrary, the internal vegetation coverage ratio is positively associated with the rank of social groups in both the fixed effect and spatial lag models (Model 5 and 6 in Table 4-2). The observation is partly consistent with some of previous findings in other Chinese cities, where public green spaces are either serving marginalized groups more, or there is no statistically significant inequality observed (Wei, 2017; Xiao et al., 2017; You, 2016).

Table 4-2 Regression results

Variables	(1) Model 1 Park OLS	(2) Model 2 Park Fixed Effects	(3) Model 3 Park Spatial lag	(4) Model 4 Vegetation OLS	(5) Model 5 Vegetation Fixed Effects	(6) Model 6 Vegetation Spatial lag
Accessibility to Parks	8.326*** (2.203)	-0.654 (1.074)	-1.480* (0.980)			
Coverage of vegetation				0.905** (0.446)	2.034*** (0.159)	1.517*** (0.195)
Constant	14.86*** (0.077)	17.58*** (0.193)	1.445*** (0.144)	14.64*** (0.170)	16.90*** (0.194)	0.874*** (0.146)
Observations	2,602	2,602	2,602	2,602	2,602	2,602
R-squared	0.005	0.891	0.807	0.002	0.897	0.811
Subdistrict	N/A	FE	lag	N/A	FE	lag

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

The results of the Mann-Whitney U test show that there is significant difference in access to green space between the two socio-economic groups (see Table 4-3). The values of their Z-scores are both negative. Thus, the residential communities with high access to public green spaces have lower socio-economic statuses and those with low access to public green spaces have higher socio-economic levels, producing similar results to the regression estimations. The residential units with higher internal vegetation coverage also tend to have lower socio-economic statuses. This is in contrast with the regression estimation, which showed a positive relationship between socio-economic level and internal vegetation. A possible explanation might relate to the selection of groups used in the Mann-Whitney U test, which only examined residential communities in the highest and lowest quartile of green space accessibility. However, the results of both tests prove that urban green space tends to benefit the lower ranked socio-economic groups, particularly the public green spaces.

Table 4-3 The results of socio-economic groups in high and low access residential communities.

Variables	High access group (median)	Low access group (median)	Mann-Whitney U test	
			Z-score	p-value
<i>Access to Parks</i>				
Socio-economic rank	0.01850	0.00016	-9.505	0.000***
<i>Access to Internal Vegetation</i>				
Socio-economic rank	0.53976	0.14002	-1.996	0.045*

Notes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The GWR output mappings indicate there are inconsistent relationships between access to public green spaces and the socio-economic status of residents. The local coefficient ranges from -0.472 to 0.841. In the map showing the spatial distribution of local relationships between socio-economic status and park accessibility, negative associations are found more among the areas uncovered by parks, while positive associations are more common in the areas close to major parks (see Figure 4-19). This map of coefficients between social groups and park accessibility is subject to both the “north-south” difference of socio-economic groups and the “wedged” pattern of urban green space distribution (see Figure 4-19).

Scenario based mapping detects that lower ranked social groups with high access to parks (the Low-High scenario) are located close to several large historical parks, such as *Tian Tan* in the center, and the Summer Palace in the northwest of Beijing, as well as newly constructed wetland parks in the southeastern periphery (see Figure 4-21). These lower-ranked groups can only afford to live in old residential communities located among underdeveloped areas of these parks, most of which come with low quality amenities and smaller areas. Fortunately, the nearby large parks and wetlands offer better green space amenities. However, planners should be advised that these areas might be redeveloped in the future, resulting in the gentrification of these neighborhoods and the dislocation of lower-class residents.

People of higher socio-economic status that have low access to parks (the High-Low scenario) tend to aggregate in and around the northwestern region, where most top university campuses and high-tech industrial parks are located (see Figure 4-21). Aside from the highly educated students, these high-tech industries attracted a large group of

high-income professionals to the area, for example, *Wu Dao Kou* subway station and *Zhong Guan Cun* industrial park are famous for nurturing high-tech firms and affiliated services. This area is also a highly ranked elementary and middle school district, again attracting large groups of elite people who tend to pay inflated prices for housing property to obtain enrollment eligibility of their children (Q. Wu, Zhang, & Waley, 2016). Some are scattered around the CBD in the east or the Capital Museum in the west 2nd ring road where parks are lacking, and this is where most of the financial businesses are located.

Lower ranked social groups with low access to parks (the Low-Low scenario) are mainly in the south of the city, between the 3rd and 5th ring roads (see Figure 4-22). The southern areas used to be heavily industrialized land and tend to contain large areas of dilapidated communities that provide cheap shelters for low-class migrant employees from other cities. These spots are potential areas to be considered in future planning to promote “green equality” due to the lower cost of land use and demand of environmental improvement. But, again, the dislocation effects of green space related gentrification might come in the process of redevelopment.

Finally, advantaged social groups with high access to parks (the High-High scenario) are close to those largest parks, such as the Olympic Green in the north, *Yu Yuan Tan* Park in the west, and *Chao Yang* Park in the east (see Figure 4-22). Evidence has shown that large parks tend to attract high quality real estate development with excellent environmental quality (Zheng & Kahn, 2013), or they are bundled with many other redevelopment projects designed to boost the overall environmental quality of areas for attracting foreign investments or hosting international events such as the Olympic

Forest, which was constructed along with many other sport facilities to host the Olympic Games. These attempts end up leaving behind a series of well-developed communities affordable to wealthier people, which make up only a small segment of the total population.

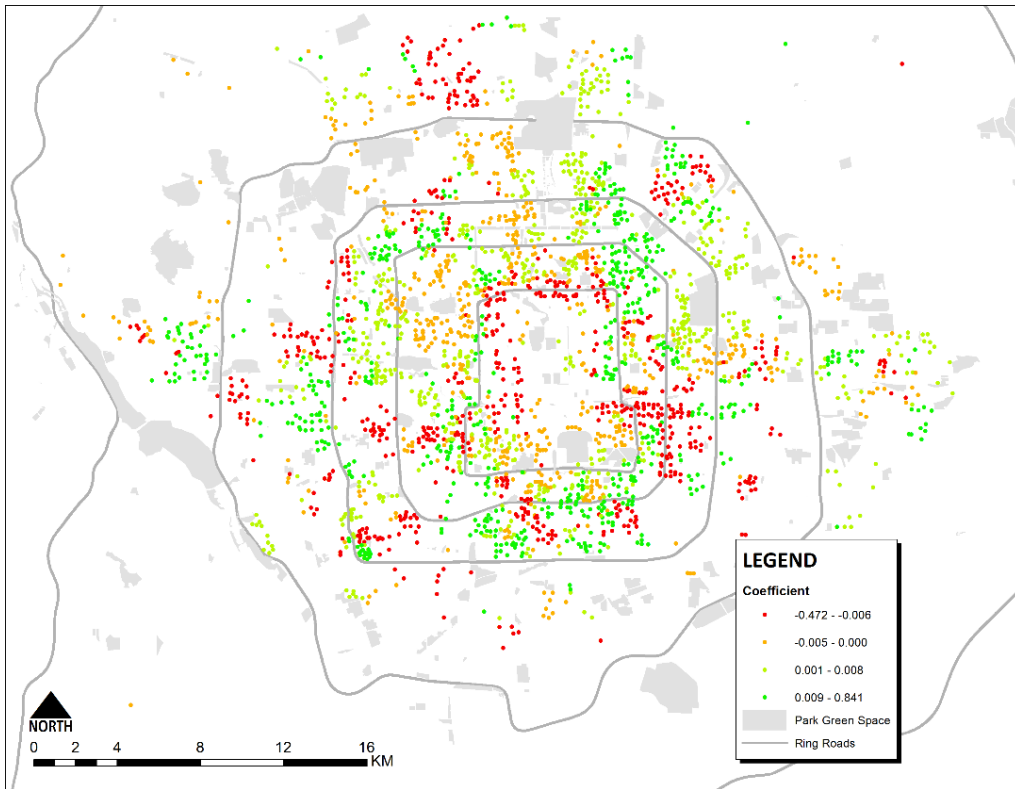


Figure 4-19 Local coefficients between access to parks and socio-economic status

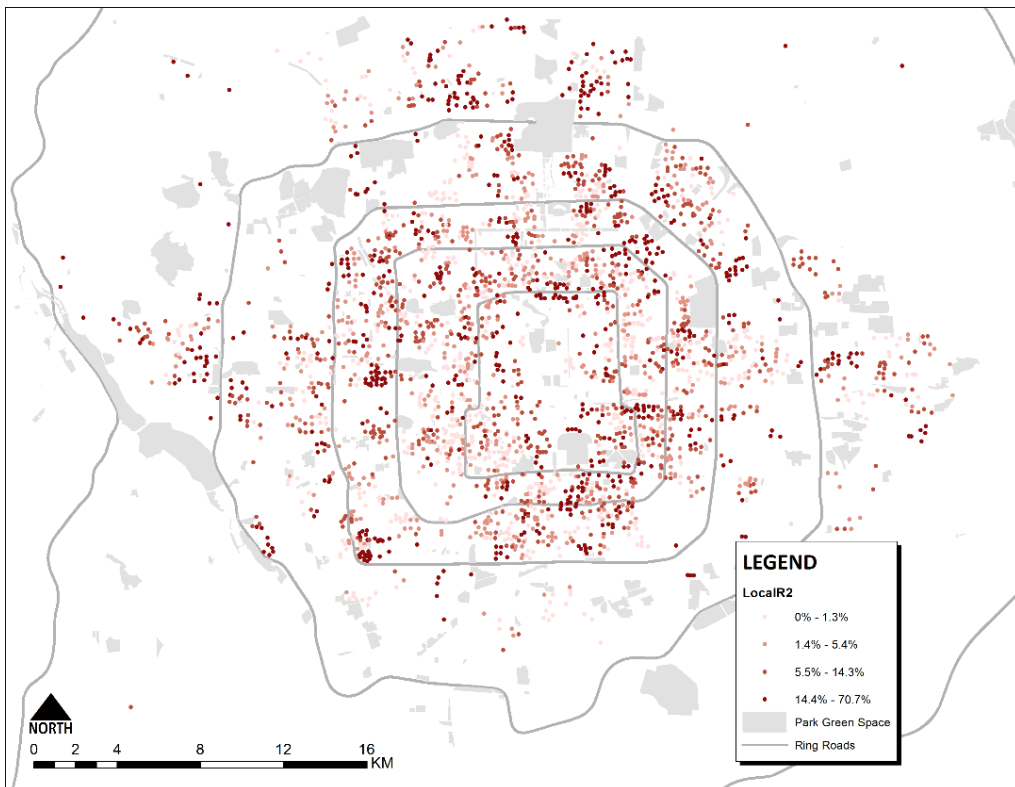


Figure 4-20 Local R-square of coefficients between access to parks and socio-economic status

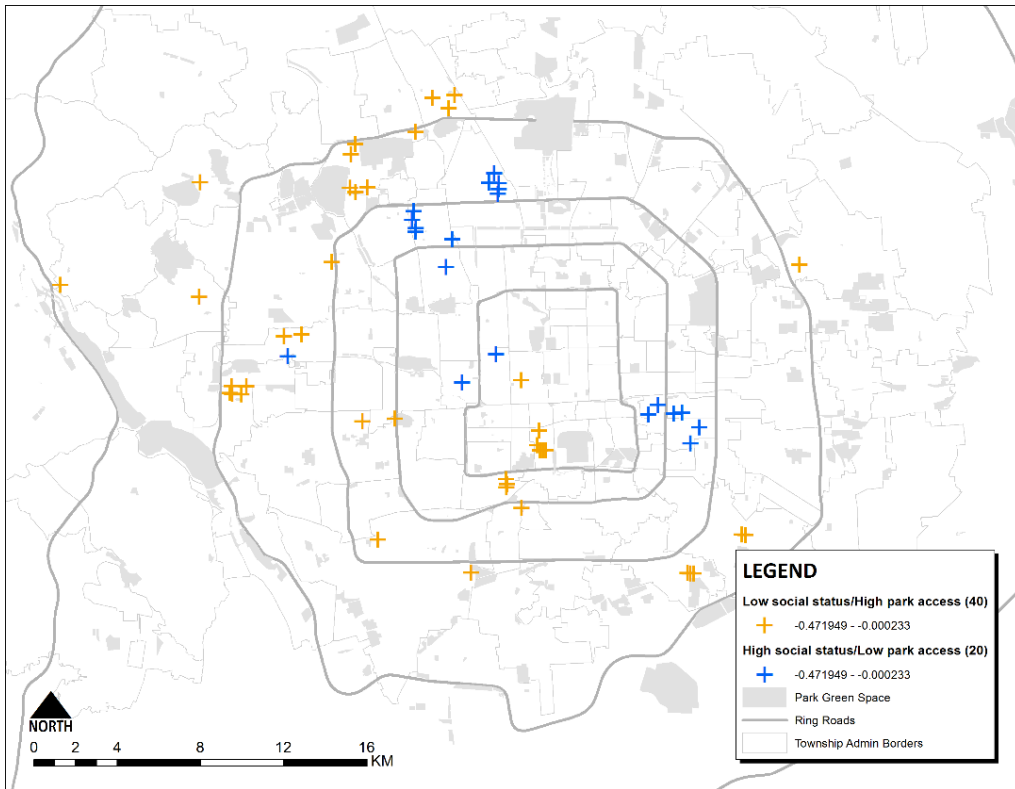


Figure 4-21 Low social status-High park access(orange) VS High social status-Low park access(blue)

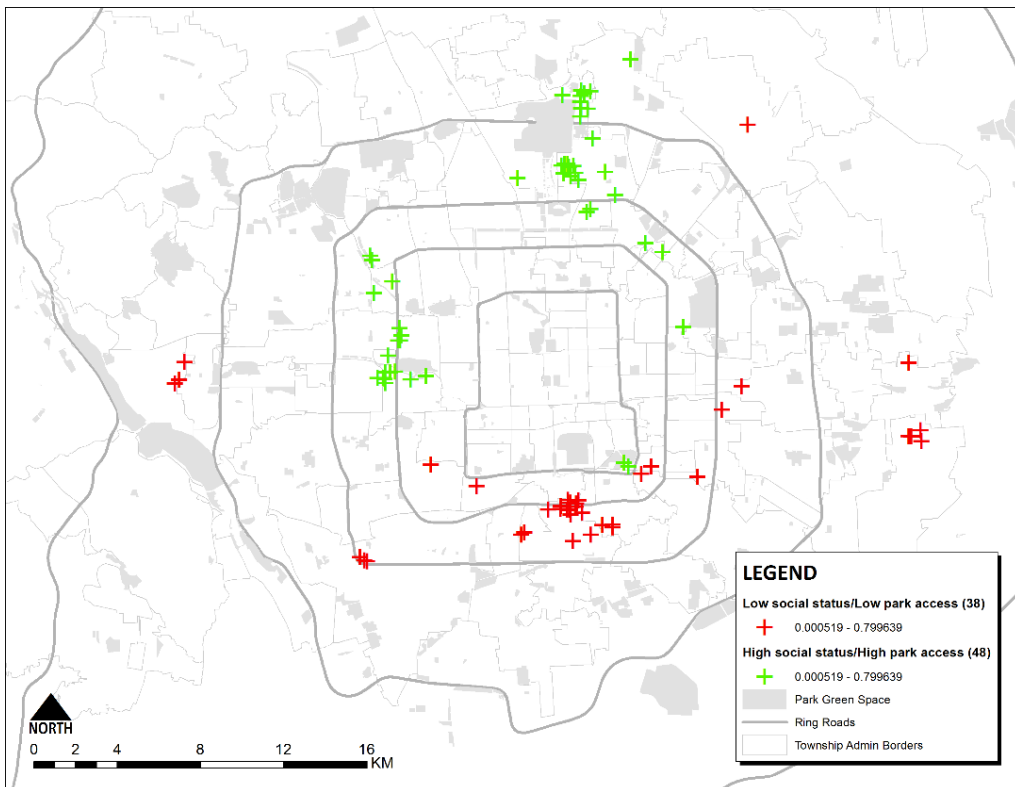


Figure 4-22 Low social status-Low park access(red) VS High social status-High park access(green)

The second coefficient between social groups and vegetation coverage shows a similar pattern, with values ranging from -17.242 to 21.534. In the distributional map, negative associations are concentrated close to the center of the city (within the 3rd ring road), against the positive associations which are relatively widely spread out into the outskirts (see Figure 4-23).

The Low-High scenarios are small in number, spreading between the 4th and 5th ring roads. These residential communities provide relatively large areas of internal green spaces which are also close to large suburban parks. The lower social status of the area might be due to its location and cheap land use. The High-Low cases are clustered around mid-sized major parks between 2nd and 4th ring roads (see Figure 4-25), where these old residential communities come with less internal green spaces. The Low-Low and High-High scenarios follow the “north-south” difference pattern (see Figure 4-26). One of the speculated reasons is that the internal green spaces are highly associated with housing prices and other factors of socio-economic status. In other words, elite groups can afford better quality inner green spaces and gardens for their exclusive use.

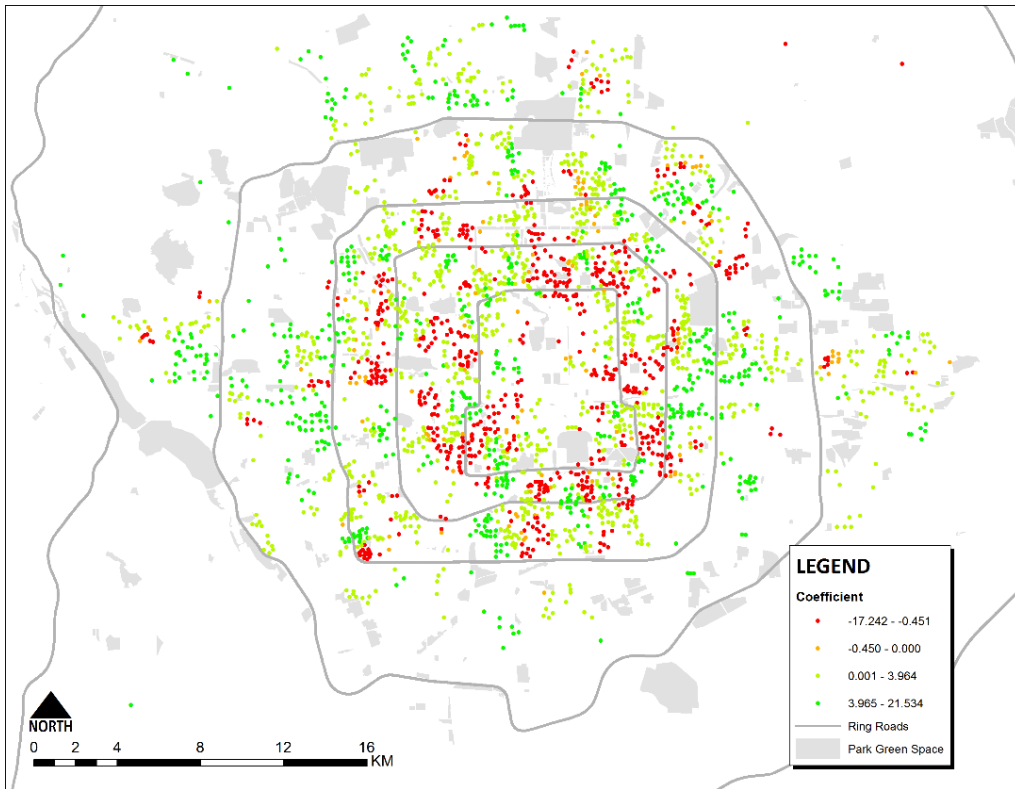


Figure 4-23 Local coefficients between vegetation coverage and socio-economic status

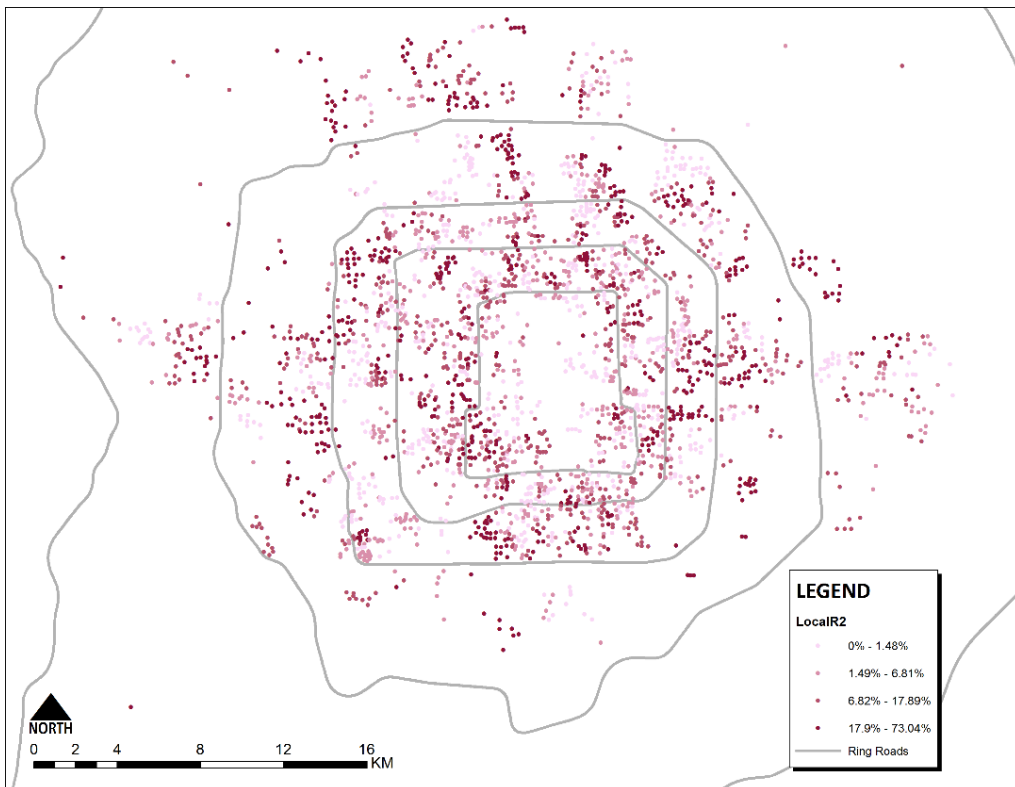


Figure 4-24 Local R-square of coefficients between vegetation coverage and socio-economic status

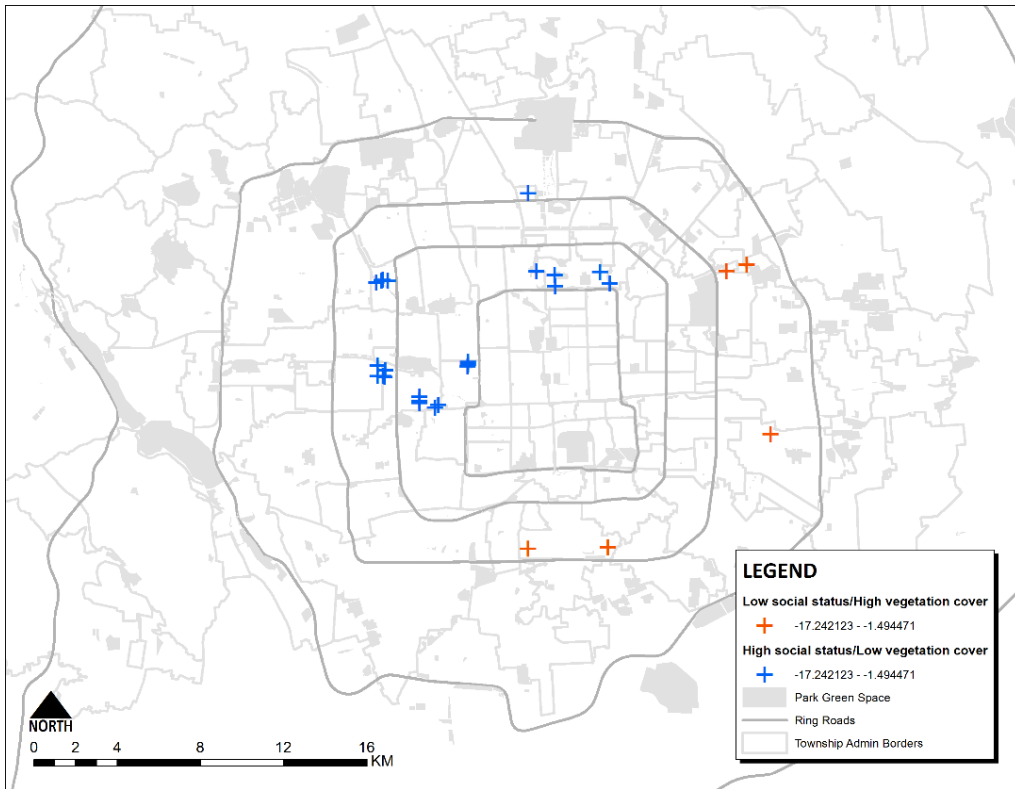


Figure 4-25 Low social status-High vegetation coverage(yellow) VS High social status-Low vegetation coverage (blue)

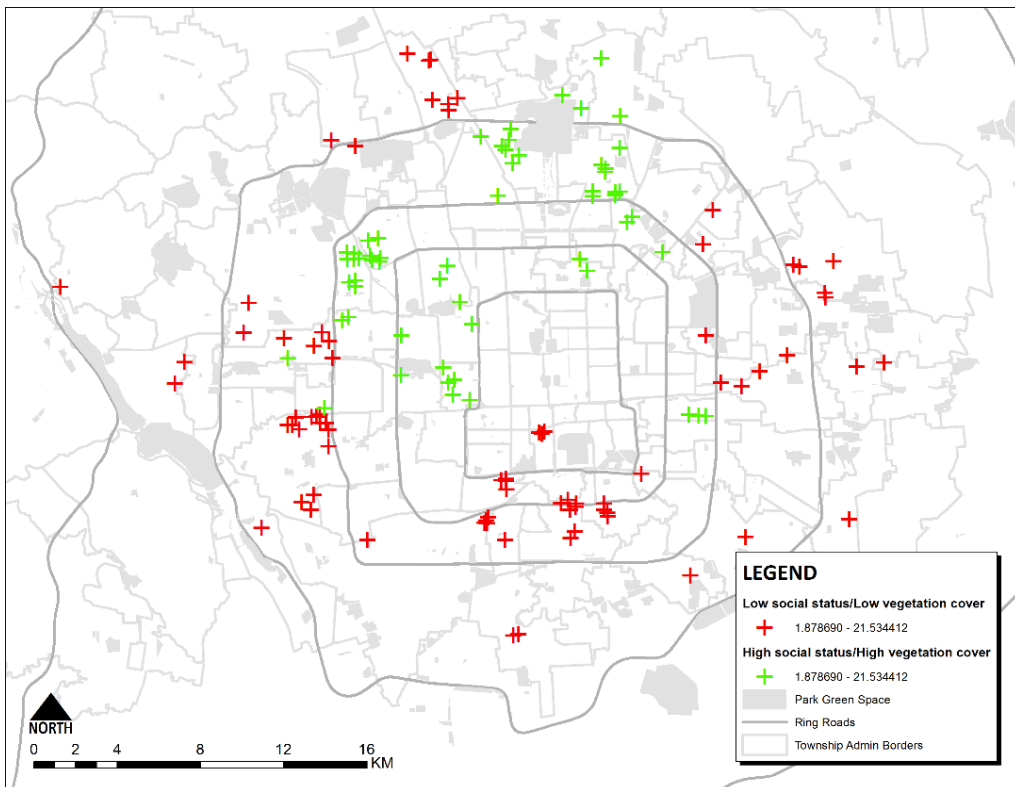


Figure 4-26 Low social status-Low vegetation coverage(red) VS High social status-High vegetation coverage (green)

4.4. Discussions

The spatial analysis confirmed large discrepancies exist among different socio-economic groups regarding their access to urban green spaces. However, the result contrasts with similar studies in the Western world. The lower level social groups in Beijing in fact have more access to high quality public green spaces than the advantaged groups; while rich people are served by more private or collective-owned gardens within the gated communities where they live. Such socio-spatial patterns of accessing green spaces in Beijing is a result of the interplay of many factors, from the original geographical characteristics, to the historical layout of the old city, urban planning and land use decisions, afforestation policies and projects, and even the public financial stresses involved in urban greening efforts.

4.4.1. Geographical Bases Set the Tone

As can be seen from above, the old city of Beijing is located in the northwest of the North China Plain, backing onto the *Yan Shan* Mountain range and facing the flat flood plains stretching toward the east and south (Beijing Local Chronicles Compilation Committee, 2016). The steep, mountainous areas in the northwest serve as natural barrier and have protected the city from the frequent harassment of nomadic peoples from further north. Ancient royal families also exploited the northwest areas in the foothills of the mountains by building palaces and royal gardens while the complicated terrain and defensive function of this landscape discouraged any further intensive development throughout history. By contrast, the southern and eastern plains, and their several rivers nourished rich land that has been fully cultivated to feed the growing population of the city for centuries.

Although the gradual development of industrialized urbanization enabled the city's capacity to expand into the peripheral natural areas, the geographical characteristics constrained the subsequent direction of growth as well as the pattern of urban greening. Upon the establishment of the PRC, the vast and flat flood plain areas in the south and east were chosen as ideal spaces to accommodate massive urban construction and agricultural development. Today, the city still sprawls into south and east areas more than other directions. The mountainous areas in the west and north remain intact for the purpose of ecological protection, in which rich vegetation in the area are preserved and flourished. This surrounding vegetation serves as a precious natural barrier to mitigate sandstorms coming from the north, which is caused by the over-exploitation of natural resources in the far north, and prevents loss of water and soil erosion. Some of natural forests on the mountain (such as *Xiang Shan* Park) are developed into accessible forest parks providing recreational spaces for the residents nearby.

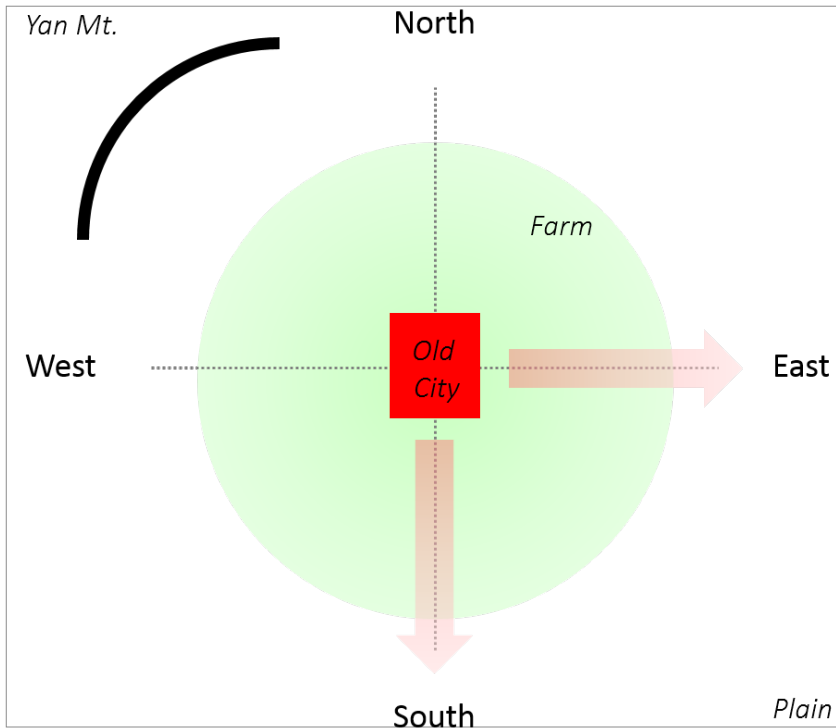


Figure 4-27 Geographical Bases Set the Tone

4.4.2. Historical Heritages Frame the Green Network

The legacies of human alteration of natural environments including the old city, the periphery farmlands, rivers and canals, and preserved mountainous areas constitute the original pattern of green spaces in Beijing, on which the urban green spaces today are drafted, implemented, and developed. As a capital city for numerous dynasties, Beijing is left with many distinct heritages, some of which come in the form of exquisite gardens and palaces with flourishing plants meant for exclusive use by the royal families and other elites of the feudalistic societies. Spatially located in the northwest city, the heritage gardens and palaces such as the famous Summer Palace attracted modern urban development in the late *Qing* Dynasty, examples of which include the Yenching University, whose campus was designed by American architect Henry Murphy (Cody, 2001). In the city center, the gradual opening of the old city's imperial palace to the

public occurred through the adoption of the western concept of park transplanted to China by the Japanese (Jijun Zhao, 2008). These royal gardens in the northwest and inner old city were the backbones of green spaces at the early stage during the post-Qing Dynasty, and still pose great impact on framing the green space networks today.

Surviving through years of wars and conflicts in the Republic of China, these large gardens were renovated and utilized to accommodate urban residents upon the establishment of the PRC. Given the difficulties of natural disasters and political turmoil in the first decade of the PRC, the green space in the inner cities were subjected to repeated damage and reconstruction processes. Some new parks were built upon undesirable spaces such as low-lying lands at that time (Beijing Local Chronicles Compilation Committee, 2000).

In the late 20th century, the subsequent yet intensive urban development placed a high priority on preserving these heritage landscapes. Many buried relics such as the former sites of moats and defensive walls built during the *Yuan* and *Ming* Dynasties were renovated and conserved as linear parks for the public. Cases can be found mostly within the 2nd Ring Road including the *Yuan* Dynasty Old Moat Park and *Ming* Dynasty City Wall Relics Park. These redevelopment projects, though small in scale, increase the public green spaces particularly in the inner city.

The productive landscape and irrigation systems on the outskirts of the city played the important role of framing the urban green space system in Beijing. Only within the last three decades has the city's growth expanded beyond the 3rd Ring Road. The influx of external investment and demand for economic development encourage Beijing to expand further into the south and east farmlands—the most feasible and low-cost areas.

Spontaneously, corresponding green spaces must be increased to mitigate the environmental issues due to urban sprawl and industrialized production activities. The vast and flat farmlands and already existing protective forests turned out to be ideal areas to install more green spaces. As a result, massive afforestation projects were launched and implemented, replacing the mono-functional, productive agricultural land with large forest parks, wetlands, and waterfront green spaces providing multiple ecosystem services.

Although the densely developed old city center (within the 2nd Ring Road today) holds many historical gardens and palaces, there is little space left for squeezing in more green spaces for the growing population and their increased demands. Efforts to meet this demand are limited but include acupuncture-style pocket garden installations often accompanied by large scale urban renewal projects. Therefore, the elite groups in the central area experienced little growth of public green spaces. What's worse, the famous heritage gardens are popular sightseeing spots attracting millions of visitors from the other parts of the country and even from across the worldwide. This limits the inner-city gardens provide to the locals, particularly during the holiday seasons or long weekends.

The marginal people living in the outskirts, fortunately, are beneficiaries of massive afforestation works on previously agricultural land in the south and east. Large areas of green spaces were recently built around the 4th and 5th Ring Road in the south and east part in Beijing. One can observe a similar situation in Shanghai, where periphery residents tend to have higher access to park green spaces (Xiao et al., 2017).

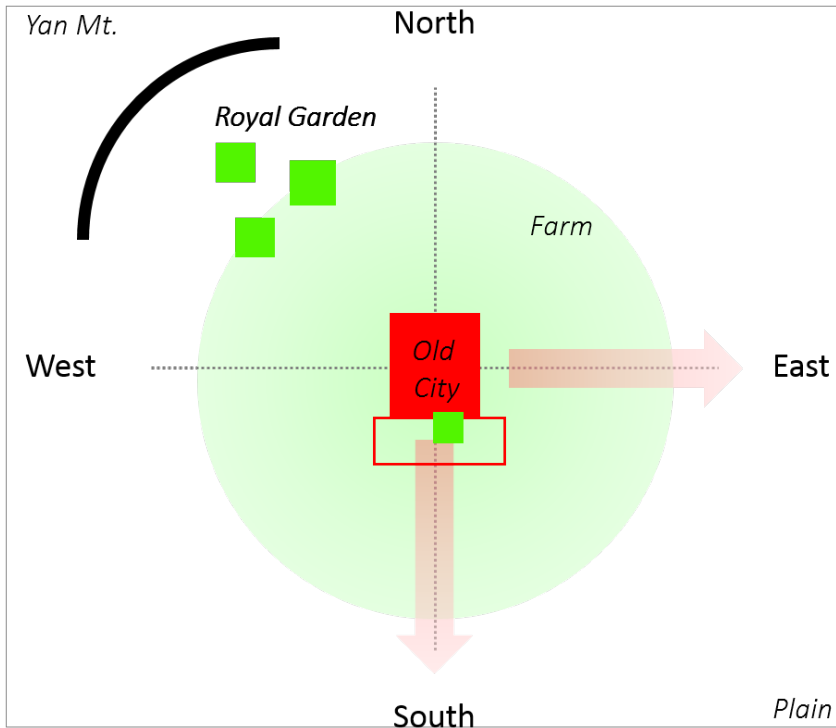


Figure 4-28 Historical Heritages Frame the Green Network.

4.4.3. The Influence of Urban Master Planning

Besides the geographical conditions and historical roots, a series of urban master plans of Beijing continue to influence the development of green spaces and the city's socio-spatial pattern. Initial urban planning concepts were introduced to Beijing from Western societies in the early 20th century. Planning projects from this era included building western style housing, opening royal gardens to the public, building roads and railways, and establishing business centers (Y. Wang, 2016b). These projects were often small in scale and scattered in the city, leaving fewer traces in the Beijing's contemporary urban pattern. Urban master plans during the socialist economy period (1950s-1980s) and the post-reform era were more influential in creating the contemporary socio-spatial pattern of green space accessibility. Due to the prioritization of industrial production during the Mao era, factories aggregated in the south and east outside of Beijing's old

city, as well as residential clusters and affiliated land use. This spatial pattern leads to accumulation of massive old residential buildings and dilapidated factories in the south and east plains. Subsequent development among these areas, though improved the living quality to some extent, the residential communities are still accommodating relatively disadvantaged socio-economic groups in the city.

Aiming to build a socialist production city, the urban master plans during Mao's era emphasized the importance of heavy industrial development (Gu et al., 2015). The first Beijing Master Plan (Beijing City Planning Commission, 1953) adopted many of the major points proposed by Soviet consultants brought on for this project. In contrast with Liang's plan, the central old city is designed to serve administrative institutions by taking advantage of existing old buildings and road infrastructures (Sit, 1996). The structure of industrial land use is determined according to the prevailing wind directions, which designates placement of major pollution-generating factories in the south and east plains outside of the old city (Beijing City Planning Commission, 1953). Northwest and west foothills including the famous *Xi Shan* (the Western Hills) are proposed to be recreational zones. These recreational areas are adjacent to numerous existing campuses for educational zones (Beijing City Planning Commission, 1953). Residential and green buffers are interspersed among all of these key land use zones of administration, industry, and education (Beijing City Planning Commission, 1953).

The 1953 concept of stressing industrial development continues in subsequent urban plans of Beijing, creating continuity in land use and green space planning across different urban plans in the following decades. (Beijing City Planning Commission, 1958, 1973; Sit, 1996). More factories and residential clusters are built in the south and east

outskirts of the old city during the “Great Leap” and “Cultural Revolution” periods, although the political chaos falsely caused negative outcomes. These include installing hazardous factories amongst residential and educational zones. As a countermeasure, green spaces were installed as buffers to mitigate pollution from factories. However, this investment was not fully implemented—forested areas were damaged during these tumultuous periods (Sit, 1996). Therefore, the land use pattern continuously influenced by these initial urban master plans rendered a distinct difference between “north and south” regarding the socio-economic statuses of residents in Beijing, where the advantaged groups live in the center and northwest regions, and the less advantaged are in the south. The investment in green space particularly in the peripheral areas lagged behind in comparison with the inner city until the new reform and open policies in the early 1980s.

After new reforms and the introduction of the open-door policy, China started to embrace a freer economy and connections to other countries. The economic development demanded more quantity and functionality of green spaces beyond prioritizing environmental protection as their sole purpose. At the city scale, green space planning approaches such as “Green Belt” were adopted in urban master plans (Beijing Municipal Commission of Urban Planning, 1982, 1992) following the practices of western cities that had implemented this method to control urban sprawl. At a smaller scale, numerous green space were associated with urban development projects to produce high quality environments that would attract overseas investment and allow for hosting of international events (Gu et al., 2015). Examples include the Olympic Forest Park and surrounding athletic facilities which were produced for the 2008 Olympic games, as well

as the Garden Expo in the *Feng Tai* district that hosted the 2012 garden exhibition, and many smaller public green spaces in the dense urban centers. Though the implemented area of green spaces, particularly the large-scale “Green Belt” projects on the outskirts, often shrink due to encroaching real estate development, the total volume of green space is steadily growing particularly at the periphery, benefiting less advantaged groups living far from the city center.

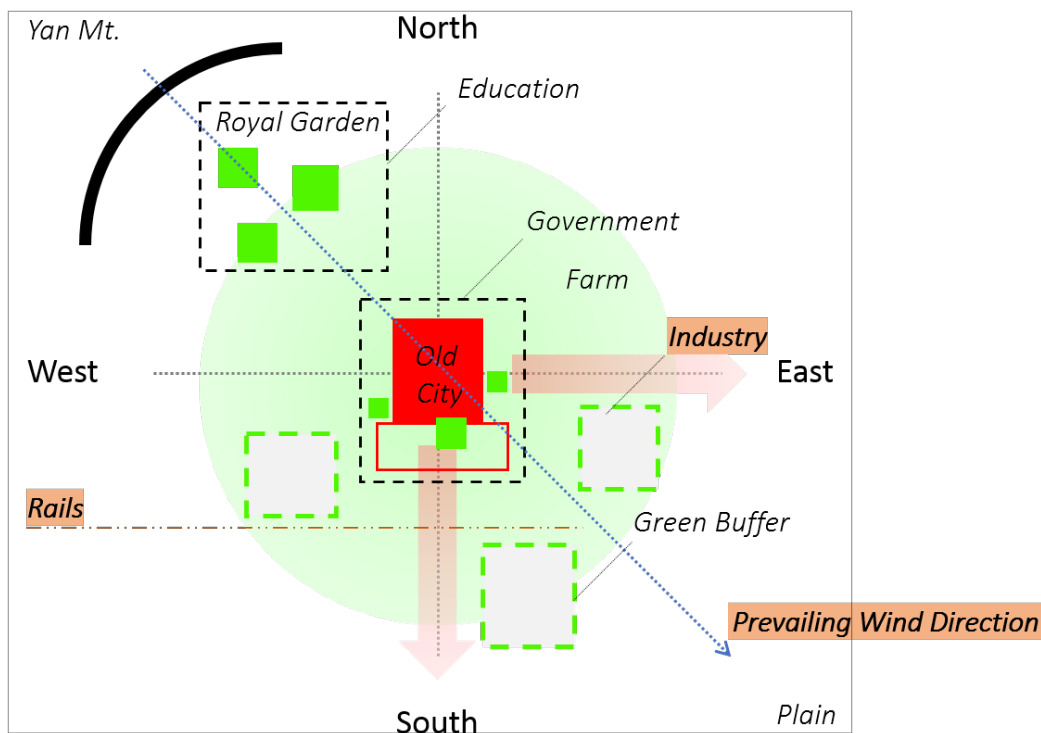


Figure 4-29 The Influence of Urban Master Planning.

4.4.4. Belated Efforts of Urban Afforestation and Environmental Concerns

Compared with other benefits of urban green spaces, the environmental mitigation function has long been the priority of urban afforestation in Beijing. However, the quality of implementation was at a poor level during the first few decades of the PRC. Only in the past two decades has urban afforestation caught sufficient attention for the government to effectively invest in green spaces. The municipality gradually introduced

more and more green spaces in all possible locations and proposed related regulations to safeguard implemented green space. Such belated efforts contribute to the large aggregation of green spaces at the periphery of Beijing, where marginalized groups are also clustered. The lateness of intervention has also contributed to the small size of parks retroactively added to the densely built old city (within 2nd Ring Road). Finally, and inadvertently, the green space pattern today serves the outskirts, lower level social groups more than the inner elite groups.

Frequently noted in the initial urban comprehensive plans of Beijing in the 20th century, the primary purpose of adding more green spaces was always to offset pollution from heavy industrial production (Beijing City Planning Commission, 1953, 1954, 1958, 1973) or to control the excessive urban sprawl and the subsequent undue consumption of natural resources (Beijing Municipal Commission of Urban Planning, 1982, 1992).

Before the 1980s, as heavy industrial production was concentrated in the flat southern and eastern plain areas, large areas of green spaces—mainly monofunctional protective forests and farmland—were located between factories. In the 1990s, the “Green Belt” concept was adopted as it was in many cities in other developed countries to control urban sprawl and the subsequent negative impact on the environment. There were three levels of “Green Belt” implemented in the urban master plans of the 1990s, 2000s, and 2010s, but most green space areas were encroached upon by other types of urban land use. Inevitably, the following urban green planning adopted the pattern of more dispersed green space and promote the “Wedged” green space pattern in the 2016-2035 urban master plan.

Such diminished quality of implementation is largely because of the lack of emphasis on urban green spaces in the urban planning sector. Urban afforestation has received less attention than other sectors such as economic development and industrialized production. Positioned as an affiliated subcategory of planning, it is often considered as a remedy after pollution becomes severe or urban sprawl reaches an uncontrollable level. The inferiority of urban green space is also reflected by the lack of related regulation and its enforcement. Previous achievement of urban green spaces such as the abovementioned “Green Belt” is often encroached by real estate development or other types of profitable land use such as golf courses.

Due to the frequent encroachment of urban sprawl and weak enforcement of policy designed to preserve urban green space, today’s inner-city residents are left with dispersed and limited volumes of green space, instead of intact “Green Belts” or distinct “Green Networks”. The fully developed dense city center does not allow further large-scale addition of green spaces. Instead, afforestation efforts are constrained to small inserts of pocket gardens and linear tree plantings linking larger patches of parks (within 2nd or 3rd Ring Road). Delayed yet sizable afforestation projects including parks, forests, and wetlands have emerged at the outskirts of Beijing. Fortunately, the recently proposed and more restrictive safeguarding policies, such as the “Ecological Red Line”, secure the intactness of afforestation efforts in the entire urban area, particularly those recent projects far from the center, thus providing disadvantaged socio-economic groups with more green spaces.

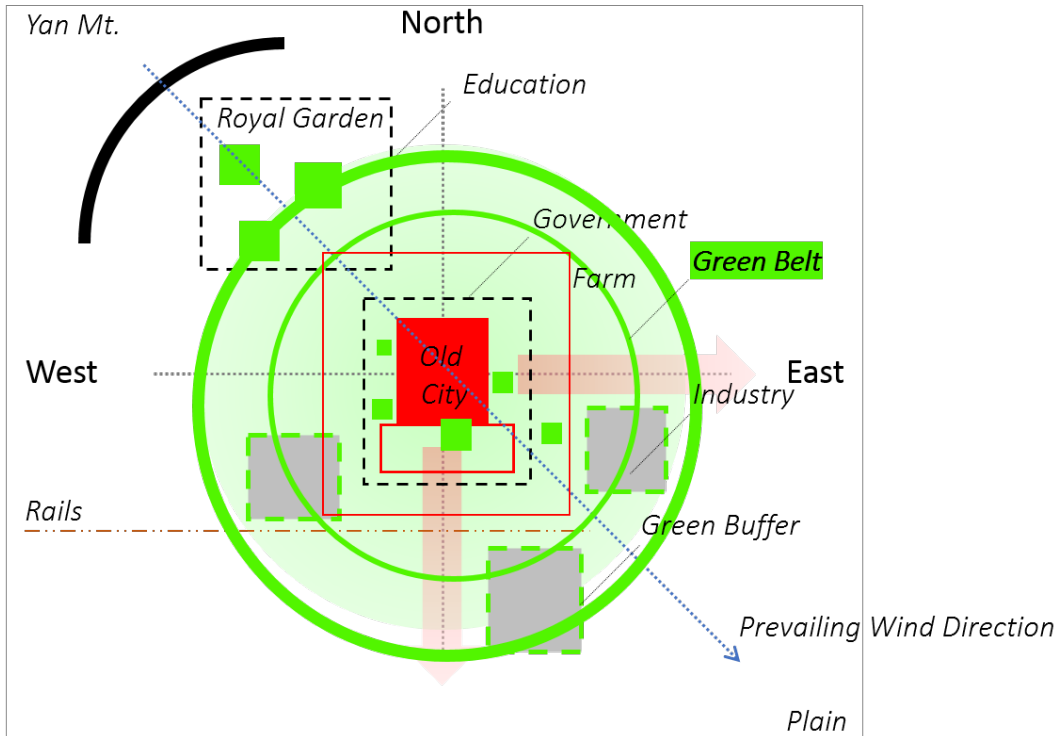


Figure 4-30 Belated Efforts of Urban Afforestation and Environmental Concerns.

4.4.5. Stress of Financial Burden and Real Estate Development

Last but not least, the funding mechanism of urban green space has contributed to an unbalanced spatial pattern of green spaces in various ways. The density and high-cost of land in the inner city does not allow large scale installation of green spaces, and large areas of cheap farmland are converted to parks on the city outskirts. However, it also unintentionally promotes more public green space aggregated around marginalized groups who are more commonly living at the periphery.

The source of financial support for funding green space installation, particularly the public green spaces such as parks, street trees, and buffer green spaces mainly comes from the government, whose major source of revenue is derived from leasing land to developers (W. Y. Chen & Hu, 2015). However, this situates the green space provision as a dilemma. The government tends to lease the high price inner city land lots to the real

estate developers for highest land revenue rather than building parks. The latter often is considered less effective for generating tangible and immediate revenues (W. Y. Chen & Hu, 2015). Common projects of urban greening in the inner-city area are the acupuncture-style interventions such as pocket gardens, which advocate to fully utilize the leftover spaces that have little value for real estate development. These “leftover” spaces might not naturally be located to the desirable areas for city residents. Instead, many are close to the underrepresented or low-quality communities where lower socio-economic groups reside, though such location selection is not specifically indicated as a priority of green space planning.

An alternative way of relying green spaces to generate more profit, though less effective than directly leasing land for commercial or residential uses, is to bolster neighboring land price by adding green spaces. This strategy prevails at the periphery of Beijing, where the lower land reclamation cost and existing vegetation allow easier implementation of large-scale afforestation projects. These large green spaces serve as an anchor project to revitalize a subcenter or intendedly attract aggregation of real estate development in the vicinity, as green spaces raise the land use price by improving the neighboring environment (Kong et al., 2007; Zheng & Kahn, 2013). Examples can be found in the massive development of Olympic Forest and the southern areas for hosting the 2008 event, and the *Feng Tai* Garden Expo project as a catalyzer for future development in the area. In these cases, the green spaces are built as real estate stimulators other than solely a public amenity. Even more, parts of large green spaces are developed for profit-driven programs such as golf courses, ecotourism, urban farming, and even private clubs. Yet, these afforestation projects are so large in scale that they still

benefit (albeit unintendedly) more communities beyond the boundaries of the original plan, some of which might be those marginal ones that are not considered in the initial development scheme.

Thirdly, the government's land financing mechanism can also encourage the replacement of planned green spaces by adopting "occupation/compensation" policies. Observed in many other cities in China, the local governments proposed policies allowing real estate developers to compensate green spaces somewhere else if they need to occupy the planned green spaces on their land lots (L. Xu et al., 2016). Such replacement activities relocate the green spaces supposed to be installed at the inner cities (often with higher cost) to the outskirts or to undesirable land far from the central city, where most marginal groups live.

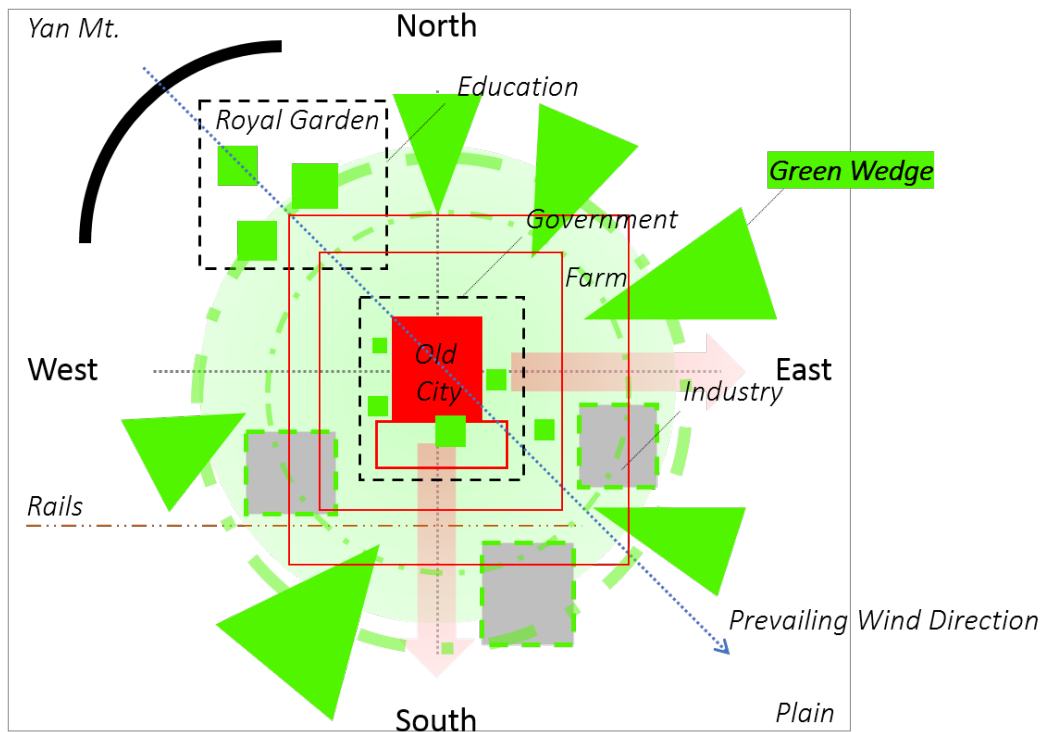


Figure 4-31 Stress of Financial Burden and Real Estate Development.

4.5. Summary of Section 4

This section examines the spatial pattern of socio-economic groups *vis-à-vis* the distributional pattern of their access to urban green space at the residential community level. The global regressions indicate that public green spaces tend to better serve the marginalized groups. Advantaged socio-economic groups are well served by internal vegetations in the gated communities in which they live. The Geographically Weighted Regression output mappings indicate that there are inconsistent relationships between access to green spaces and the socio-economic status of residents. The socio-spatial patterns of accessing green spaces in Beijing is a result of the interplay of many factors, from the city's original geographical characteristics, to the historical layout of the old city, urban planning and land use decisions, afforestation policies and projects, and even the public financial stresses involved in urban greening efforts. The result of this analysis identified locations that might harbor inequalities in the accessing of public green spaces. Such information allows decision makers and planners to accurately invest in afforestation projects for the purpose of promoting social equality, especially for those groups with lower levels of accessibility to green spaces.

5. The Allocating Process

This section investigates the trend of changing accessibility to urban green spaces in different socio-economic groups between the years 2000 and 2010. The following questions will be answered:

- Are more urban green spaces provided to advantaged socio-economic groups?
- If so, what are the attributes of these urban green spaces?
- How are the trade-off and/or synergy of benefits of urban green space among different social groups distributed for the given period?

5.1. Introduction

Beijing municipal government has substantially invested in urban greening projects in order to mitigate environmental degradation since the early 21st century. As a result, the overall volume and quality of urban green spaces has greatly improved. However, decision-makers and urban planners focus more on the ecological benefits of green space, often overlooking the socioeconomic consequences, some of which might lead to undesirable outcomes, such as environmental inequality. By comparing the changes in means of access to urban green spaces and socio-economic statuses, this section investigates whether the afforestation projects during 2000 and 2010 favor advantaged groups, and further assesses the synergetic and/or trade-off effects of different benefits in the process.

Admitting that green spaces are not homogeneous entities and so are capable of delivering multiple benefits to urban residents, the trade-off and/or synergetic effects of such varying benefits have been present over the course of the afforestation processes. However, most of the previous studies on social equality of green spaces only consider certain, limited types or benefits of green spaces, such as parks or public green spaces and their recreational service (Wei, 2017; Xiao et al., 2017; Yasumoto et al., 2014; You, 2016). In fact, even a single type of green space might deliver multiple ecosystem services including entertainment, micro-climate adjustment, air purification and more. During urban development, the multiple services within park green spaces or forests also change through trade-off and/synergetic effects. For instance, turning a protective buffer forest into a park results in a similar level of environmental regulating capacity but improves its capability of providing more recreational spaces.

Additionally, the changing geo-morphological patterns and social economic contexts emerging during urban sprawl and renewal processes might lead to dynamic results in the patterns of urban greening and the subsequent services provision. Existing literature has focused more on the evaluation of trade-offs among multiple benefits of green spaces as they related to processes of urban sprawl and land use changes (Lauf, Haase, & Kleinschmit, 2014; Sun, Lu, Li, & Crittenden, 2018; Z. Wang et al., 2015; Zhou & Wang, 2011). Such research, however, fails to integrate the spatial changes and distribution of different socio-economic groups in a city—i.e. the beneficiaries of varying services provided by green spaces, and the changing demands of these groups. Involving such changes of socio-economic statuses might generate entirely different results. For example, again, turning a natural forest to urban parks could deliver only minor improvements in environmental regulating services. But if the neighboring residents are increased, such adjustment can benefit more residents and provide more opportunities for recreation, and finally improve physical and even mental health of people living around (Ekkel & de Vries, 2017; Zhou & Parves Rana, 2012). On the other, the replacement of the agricultural lands with forested parks reduces food production while providing more recreational and leisure services to the public, with the result being that the latter might be more welcomed by increased number of residents in urban development process.

5.2. Data and Methods

5.2.1. Data for Determining Socio-economic Groups

The study area in this section includes six subdistricts of Beijing—*Dong Cheng*, *Xi Cheng*, *Hai Dian*, *Chao Yang*, *Shi Jing Shan*, and *Feng Tai* (see Figure 5-1). The Chinese population census at the Township level in Beijing is the only available source to keep track of socio-economic changes. The census unit tract follows the administrative divisions as a basic unit (Beijing Municipal Statistics Bureau, 2010). However, Beijing administrative divisions at the Township level (including *Jie Dao*, *Xiang*, or *Zhen* in this case) were subject to a series of re-adjustments between 2000 and 2010. In order to compare the changes of different social groups as well as the overall volume of available green spaces between the two years (2000 and 2010), a same administrative area between the two is necessary. That is, for example, whereas there were only three Township level census tracts used on the 2000 Census, four were used for the 2010 Census. The author have therefore unified the administrative borders of the 2000 and 2010 Censuses to make them spatially consistent, relying on official documentations and a series of administrative maps (Beijing Institute of Surveying and Mapping, 2016; Beijing Municipal Bureau of Civil Affairs, 2015). The attribute of socio-economic census data is also merged to match the new administrative units for longitudinal analysis. The information of changes of administrative divisions at the Township level come from a local gazetteer (Beijing Civil Affairs Bureau & Beijing Institute of Surveying and Mapping, 2007). See Appendix 8.3 for detail description of unifying administrative changes.

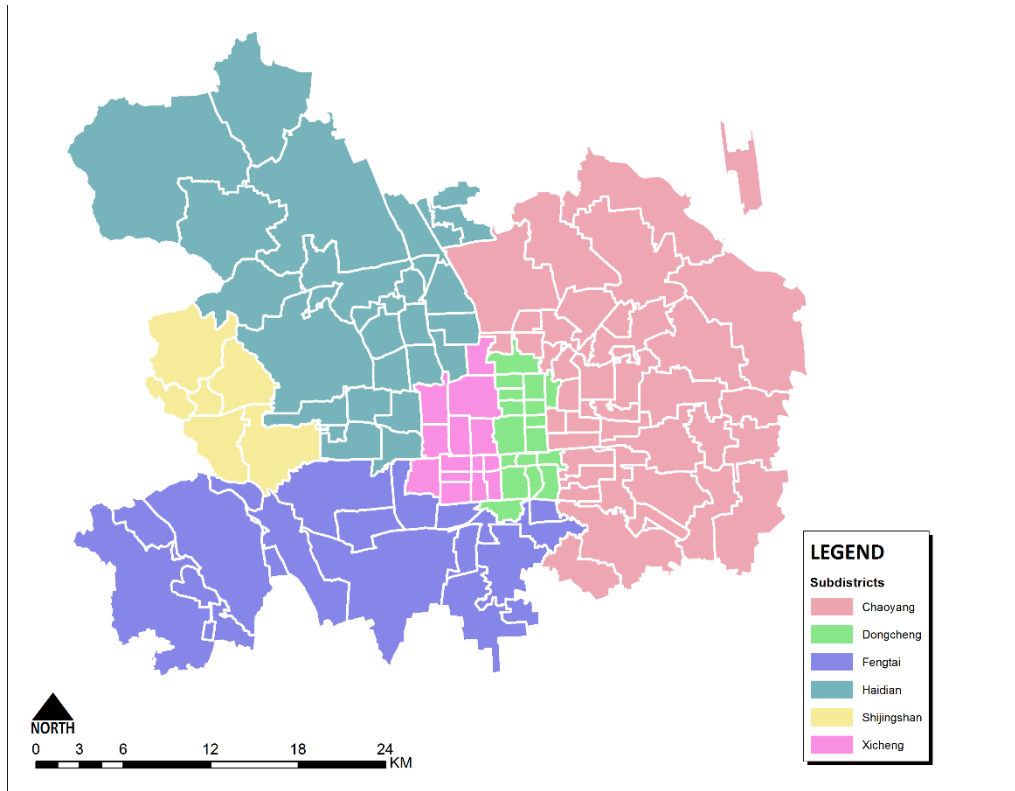


Figure 5-1 Six districts and adjusted subdistricts.

Official census data can provide demographical information of residents in each Township level census tract. Four indicators are chosen to distinguish different socio-economic groups: employment rate (see Figure 5-2 & Figure 5-3); percentage of residents with local household registration²⁰ (see Figure 5-4 & Figure 5-5); percentage of population with bachelor degree or above (see Figure 5-6 & Figure 5-7); house area per capita (see Figure 5-8 & Figure 5-9).

²⁰ The study selected those “who have resided in the township, towns and street communities for more than 6 months but the places of their permanent household registration are elsewhere” according to the definition of 2000 and 2010 census as non-local household.

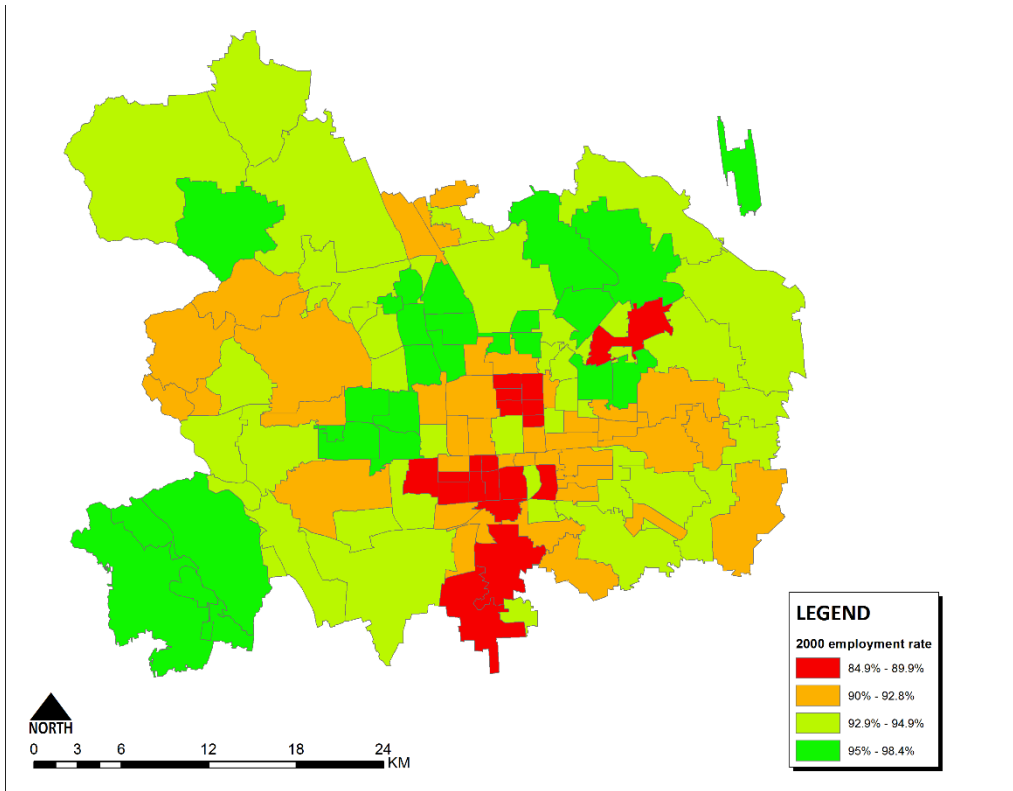


Figure 5-2 Employment rate in 2000

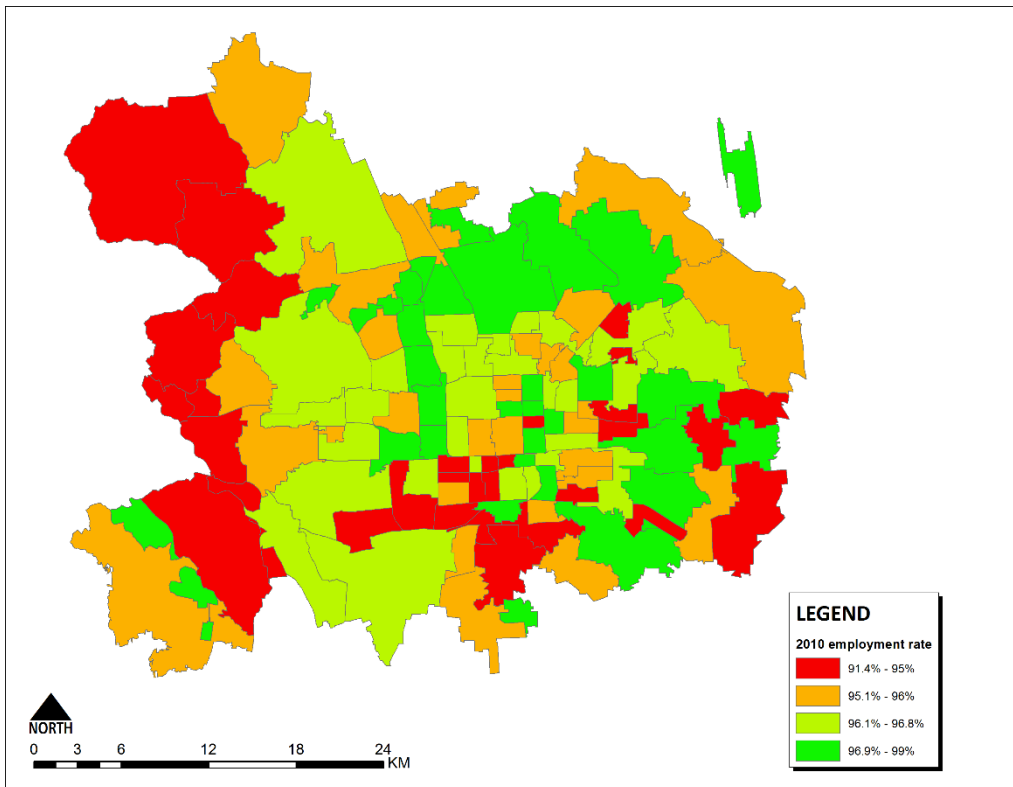


Figure 5-3 Employment rate in 2010

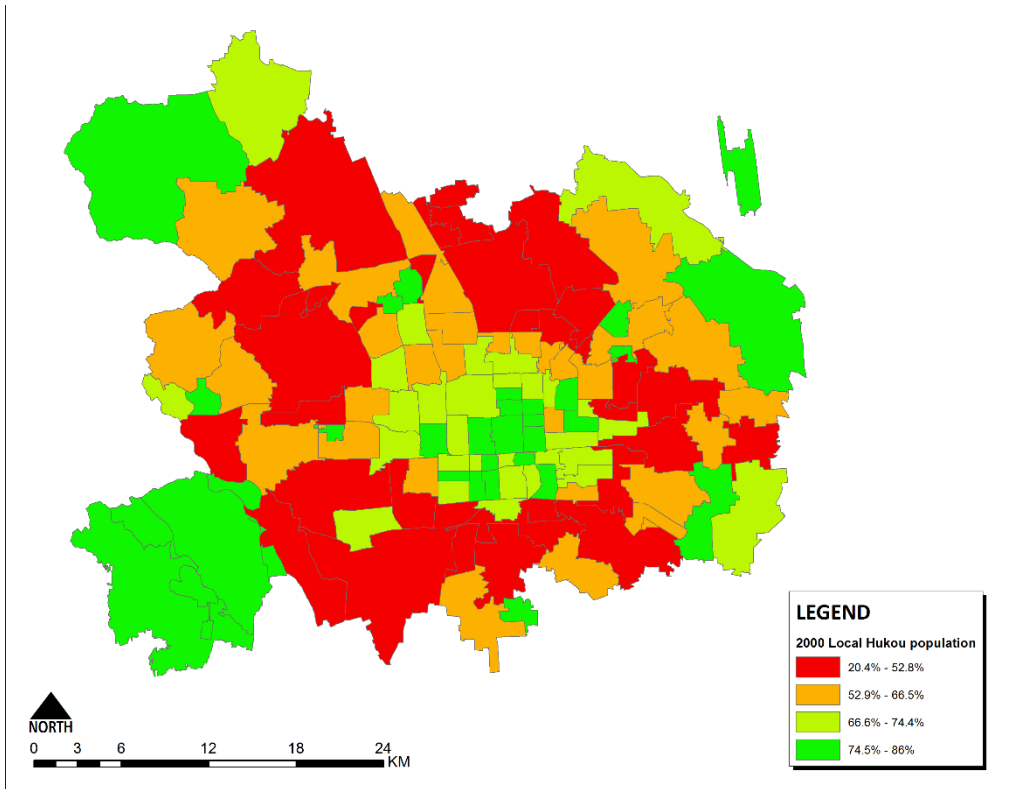


Figure 5-4 Percentage of local Hu Kou residents in 2000

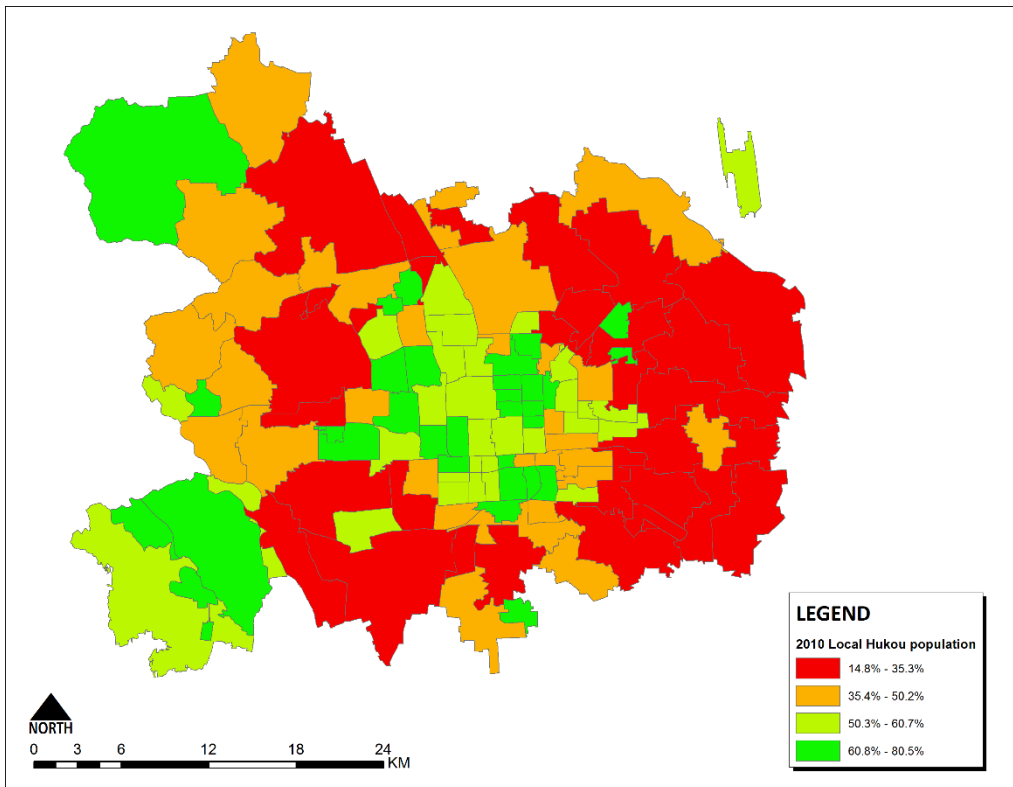


Figure 5-5 Percentage of local Hu Kou residents in 2010

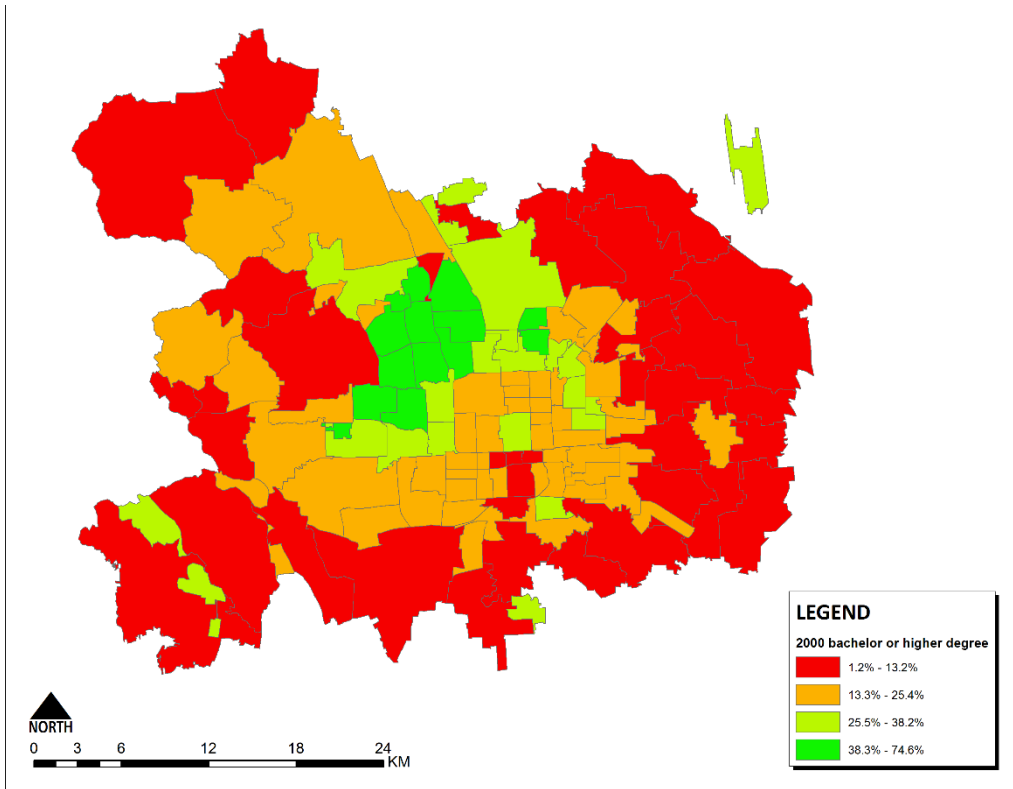


Figure 5-6 Percentage of people with bachelor or higher degree in 2000

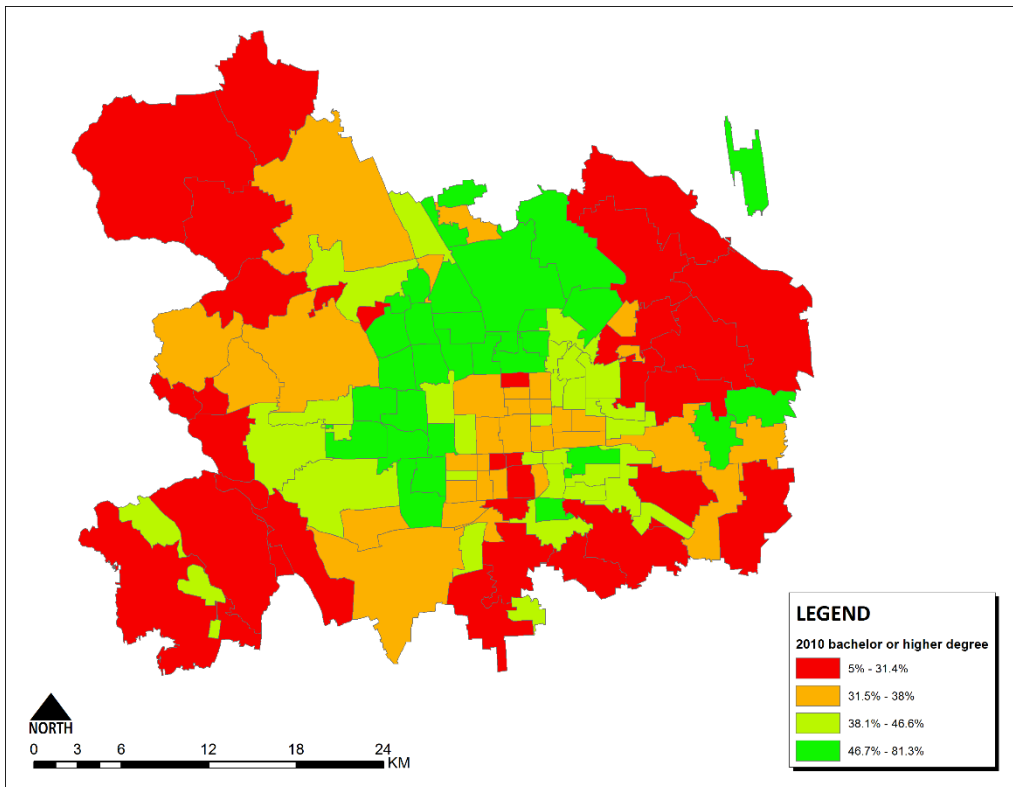


Figure 5-7 Percentage of people with bachelor or higher degree in 2010

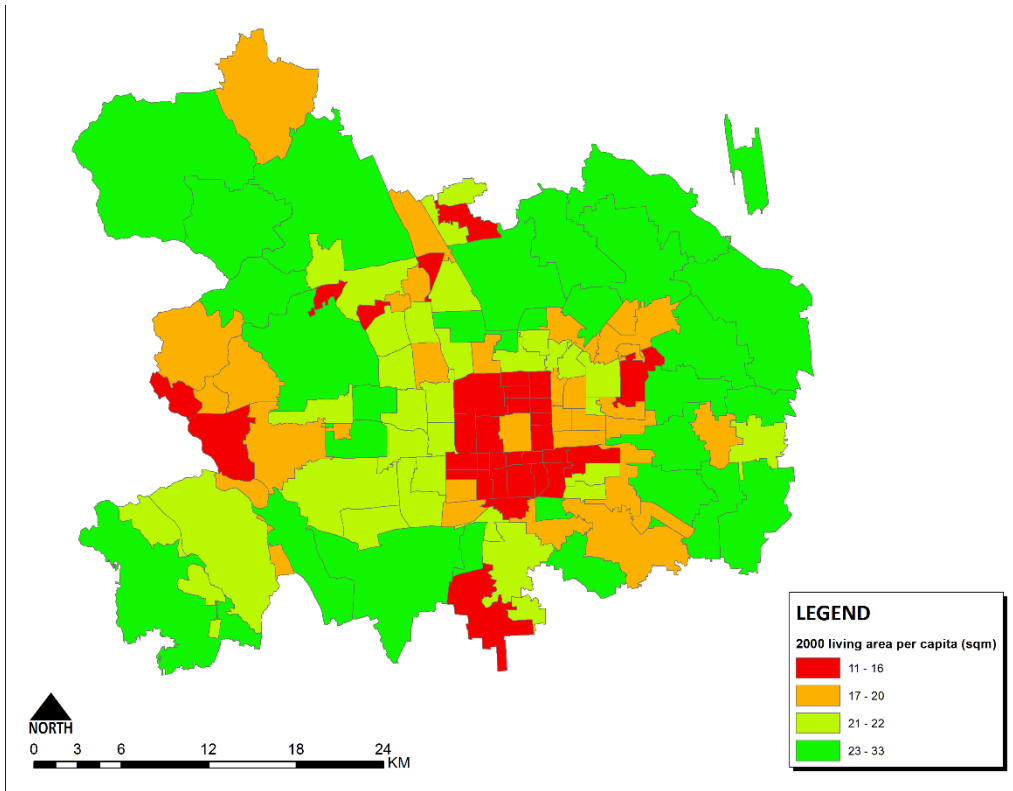


Figure 5-8 Housing area per capita (sqm) in 2000

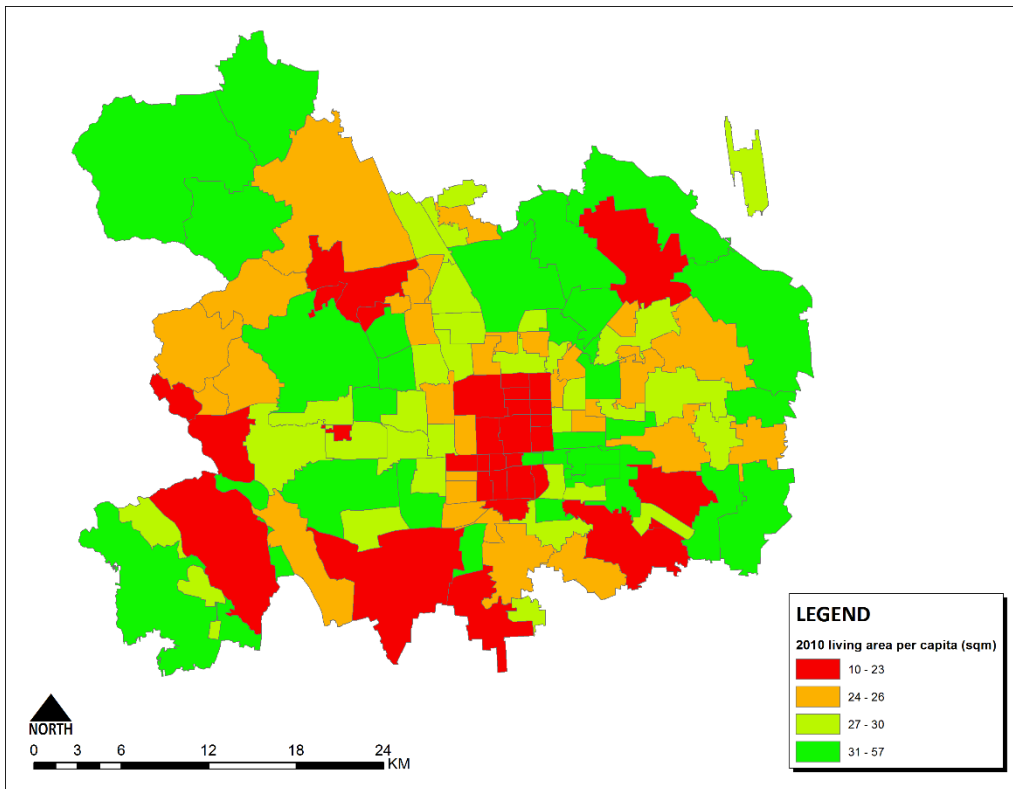


Figure 5-9 Housing area per capita (sqm) in 2010

5.2.2. Measuring Accessibility to Urban Green Space

Due to the widely varying boundaries of census tracts, as well as the unavailability of land use data from both years, the measurements of accessibility to urban green spaces utilizes urban built up areas as a basic unit instead of residential communities in the previous section. This goes as follows: first, freely available Landsat images (M. C. Hansen et al., 2013) with a resolution of 30m were obtained for both the years of 2000 and 2010, respectively; next, a supervised classification is conducted to detect constructed land of each 30m pixel; then, a grid is created across the study area with a resolution of 200m, which is the average size of residential communities in Beijing according to the data collected in the previous section; and finally, each 200m cell is assigned to be urban land if it has 50% or more constructed land.

Two accessibility indexes again are calculated for each Township census tract (respectively) reflecting the environmental regulating and recreational benefits of green spaces (see Figure 5-10). The recreational benefit is reflected by the accumulated Gravity Model based accessibility index to public green spaces from each centroid of 200m urban land cell (see Figure 5-13 & Figure 5-14).

The formula of Gravity Model based accessibility is:

$$GA[i]^r = \sum_{j=1}^n \frac{S_j}{e^{\beta \cdot d[i,j]} P_i}$$

for $d[i, j] \leq r$

where

$GA[i]^r$: Gravity Model based accessibility of each cell i.

S_j : the size in hector of public green space j.

β : an exponential value for adjusting the effect of distance decay. This study used the distance decay effect β with 0.002 in meter unit, from Handy and Niemeier's study on pedestrian trips to retail facilities in Oakland, CA (Handy & Niemeier, 1997).

$d[i, j]$: nearest linear distance between community i and the public green space j.

r : the search radius using 1600m in this case.

P_i : the population of a grid cell equals to total population of the census tract divided by number of urban land use grids of that tract.

The regulating index is measured by the area of vegetation per capita in a given census tract (see Figure 5-17 & Figure 5-18). Vegetation area in each Township census tract derives from total area of pixels with NDVI value higher than 0.1 utilizing Landsat imageries (M. C. Hansen et al., 2013). The threshold value is determined based on previous studies using similar data set (B. Chen, Nie, Chen, & Xu, 2017; Nesbitt, Meitner, Girling, Sheppard, & Lu, 2019).



Figure 5-10 Conceptual diagram of measuring access to parks (left) and urban vegetation (right).

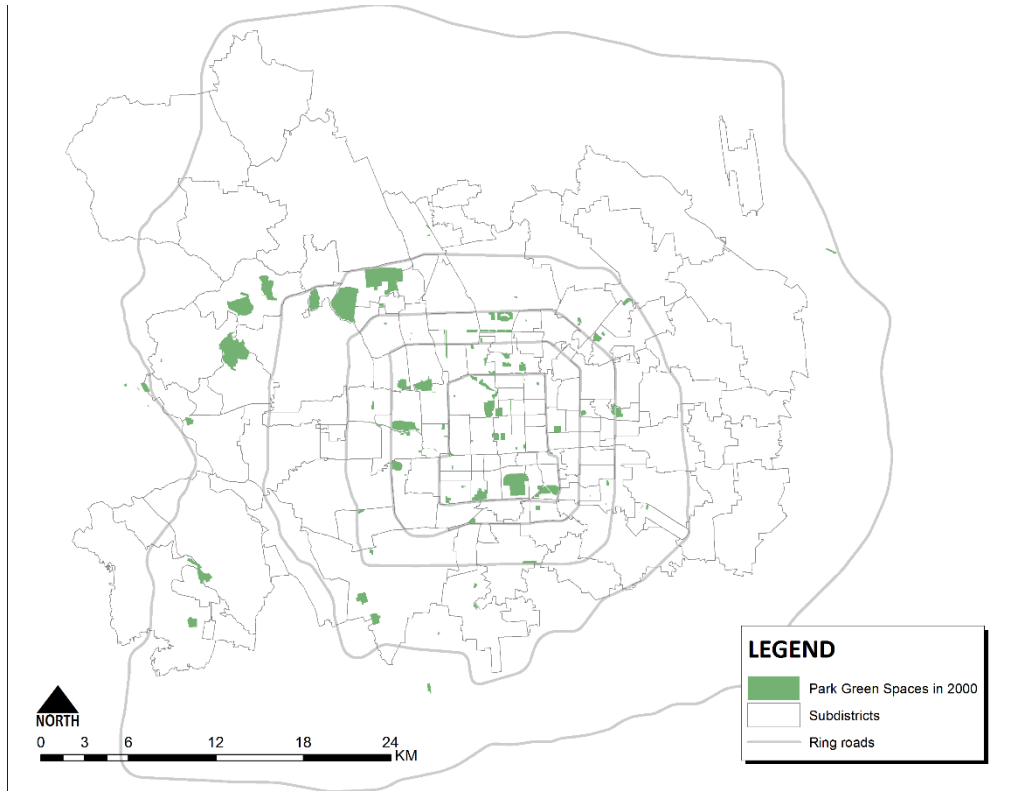


Figure 5-11 Public green spaces in 2000

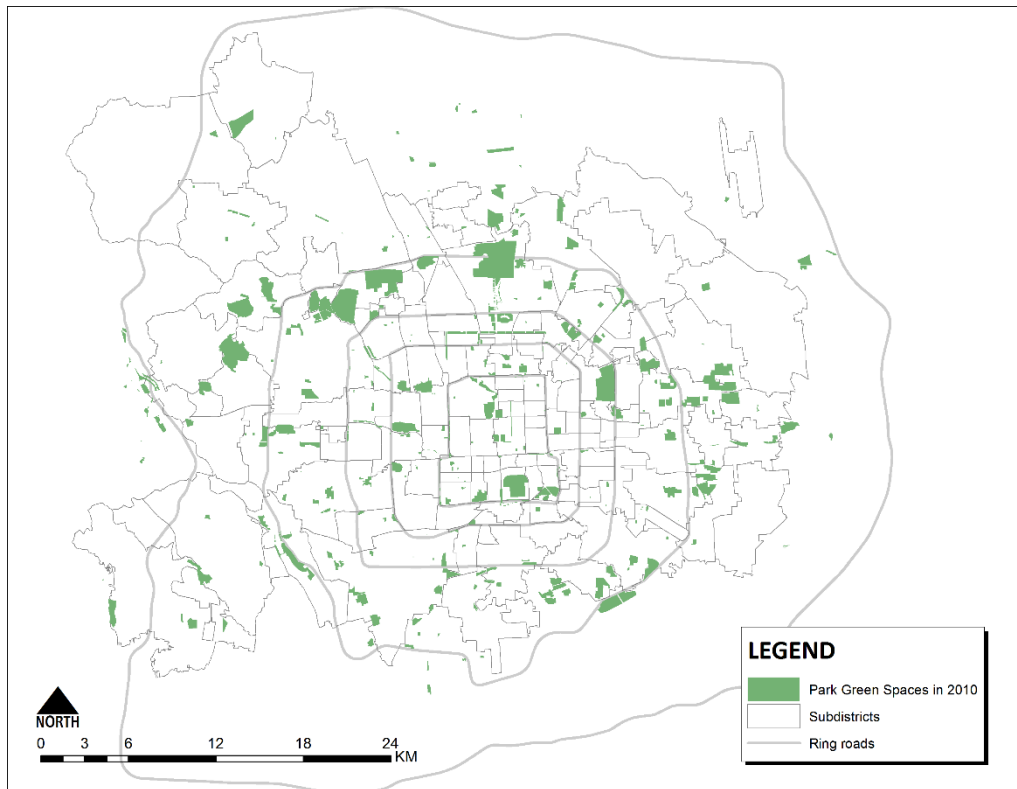


Figure 5-12 Public green spaces in 2010

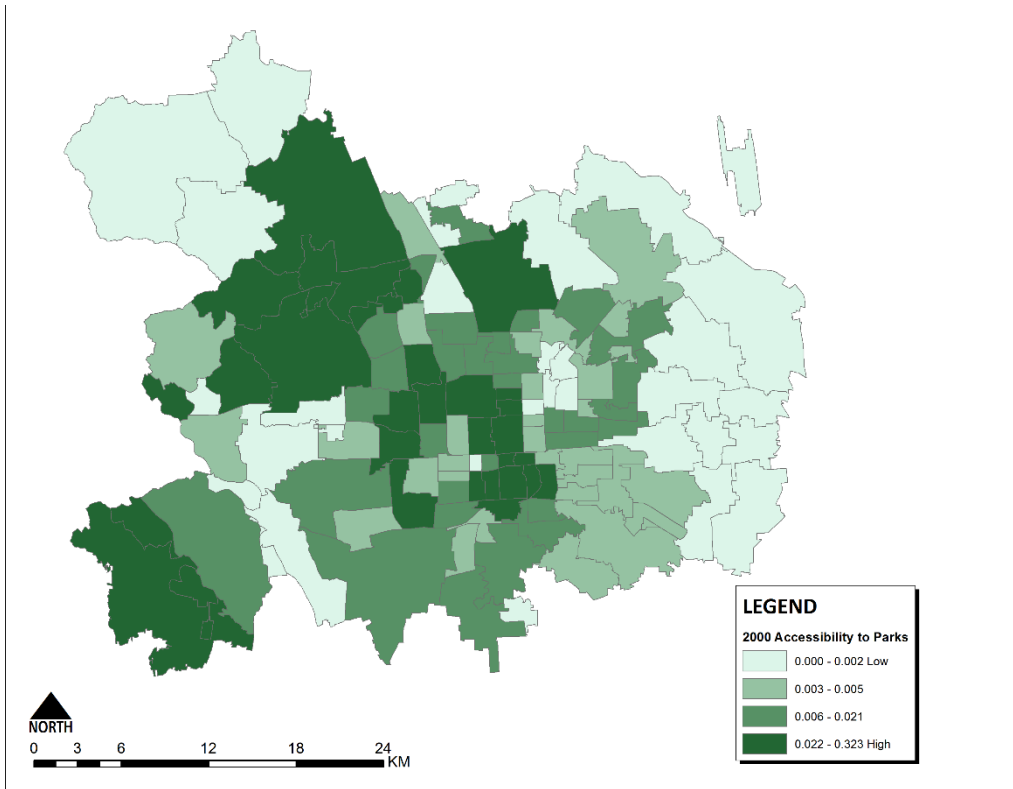


Figure 5-13 Accessibility to public green spaces in 2000

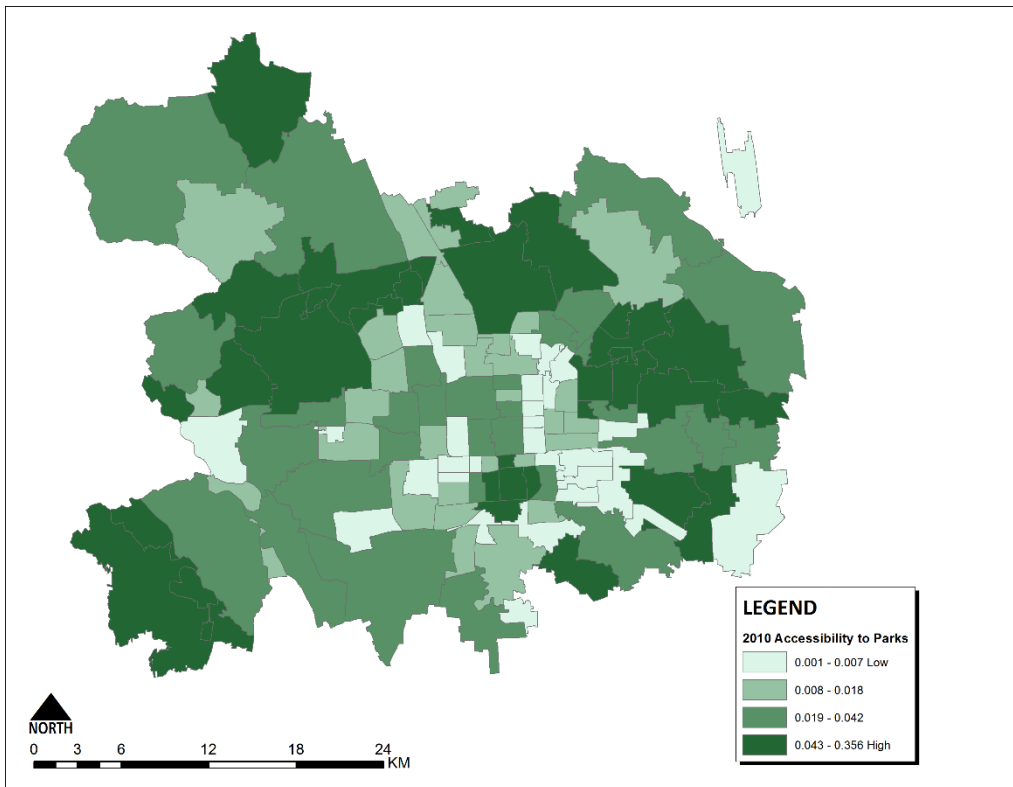


Figure 5-14 Accessibility to public green spaces in 2010

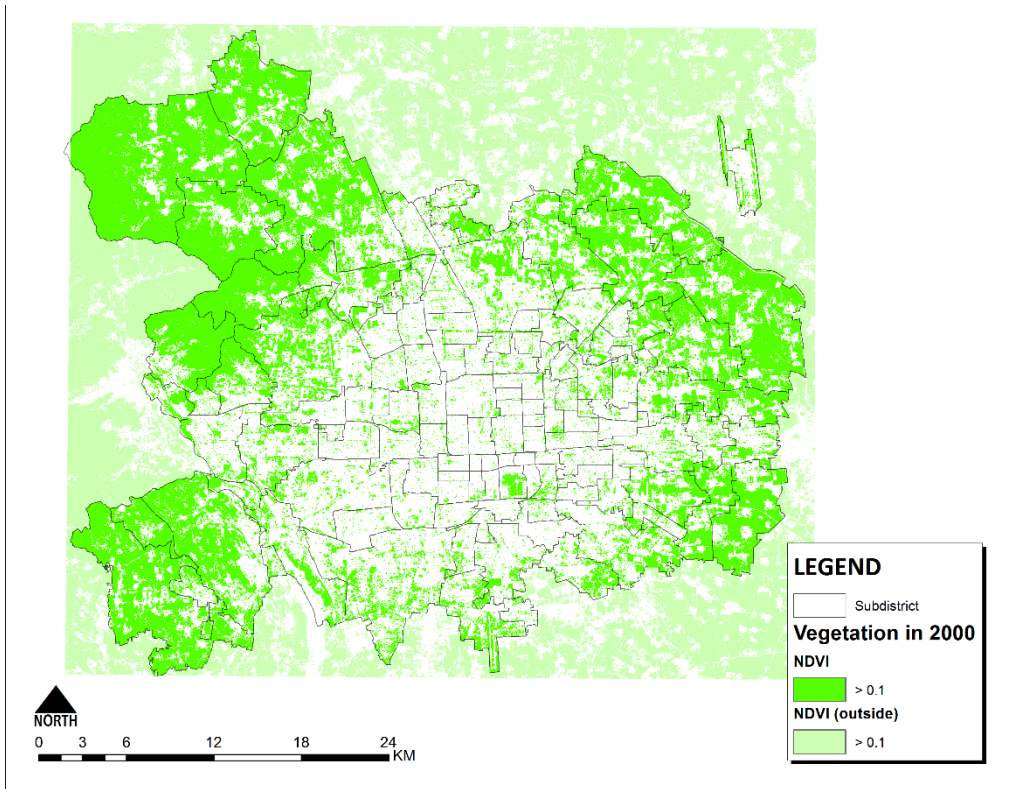


Figure 5-15 Urban vegetation coverage in 2000

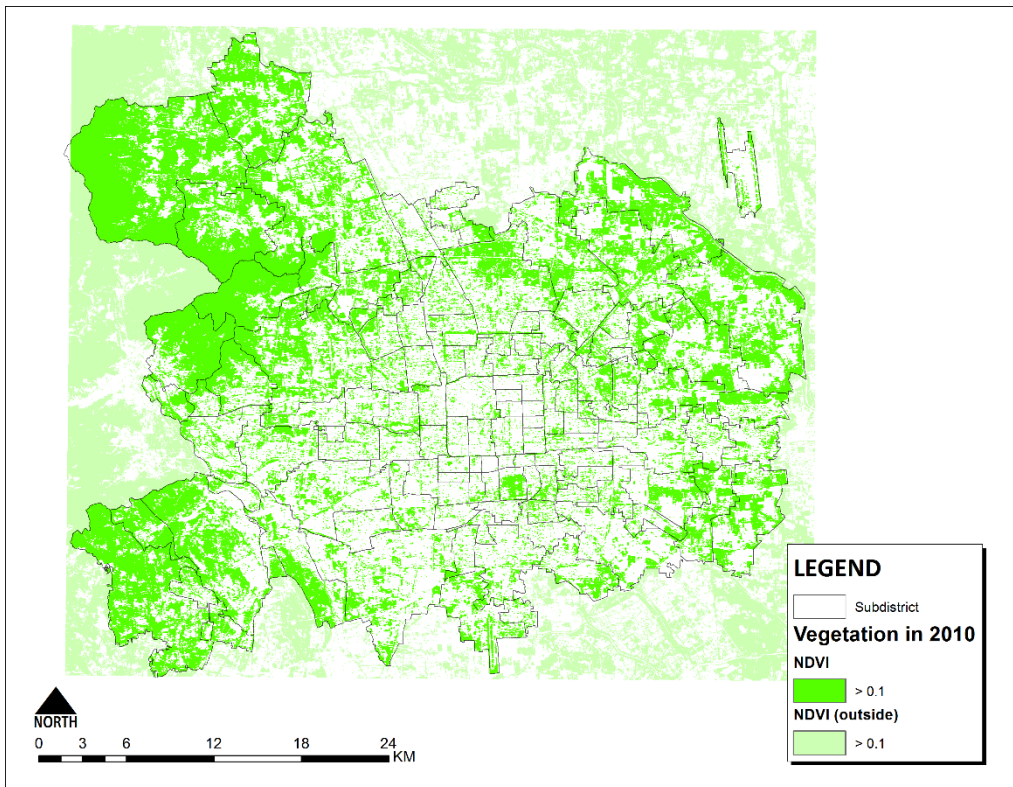


Figure 5-16 Urban vegetation coverage in 2010

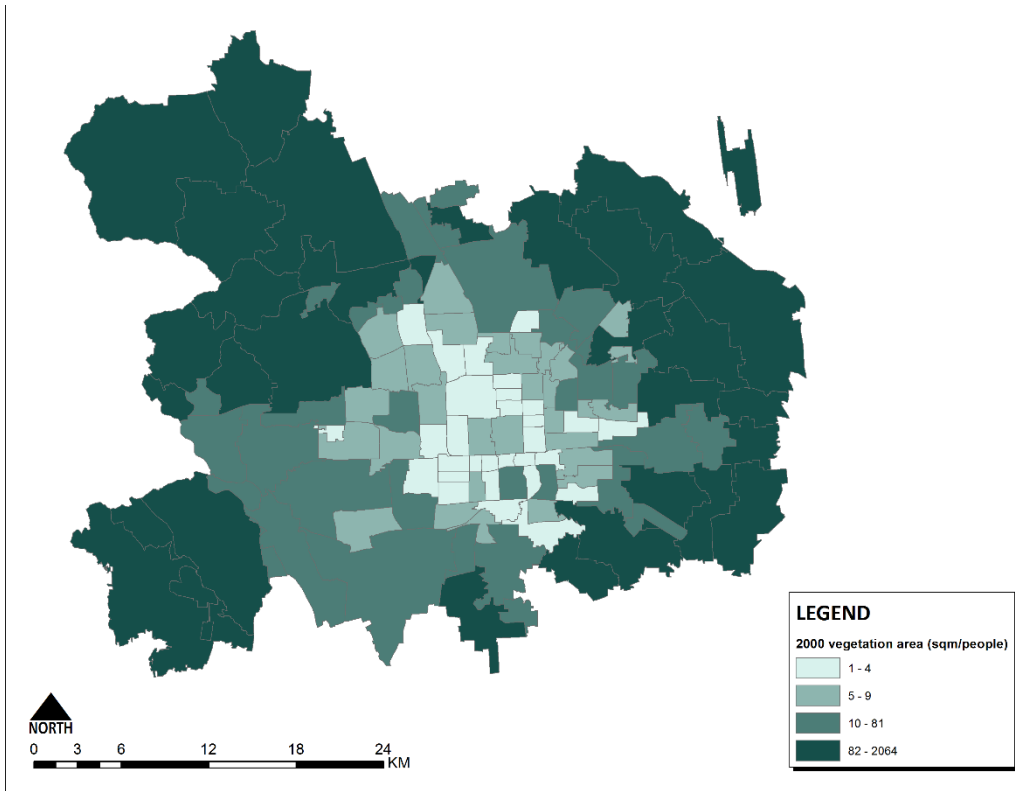


Figure 5-17 Area of vegetation per capita in 2000

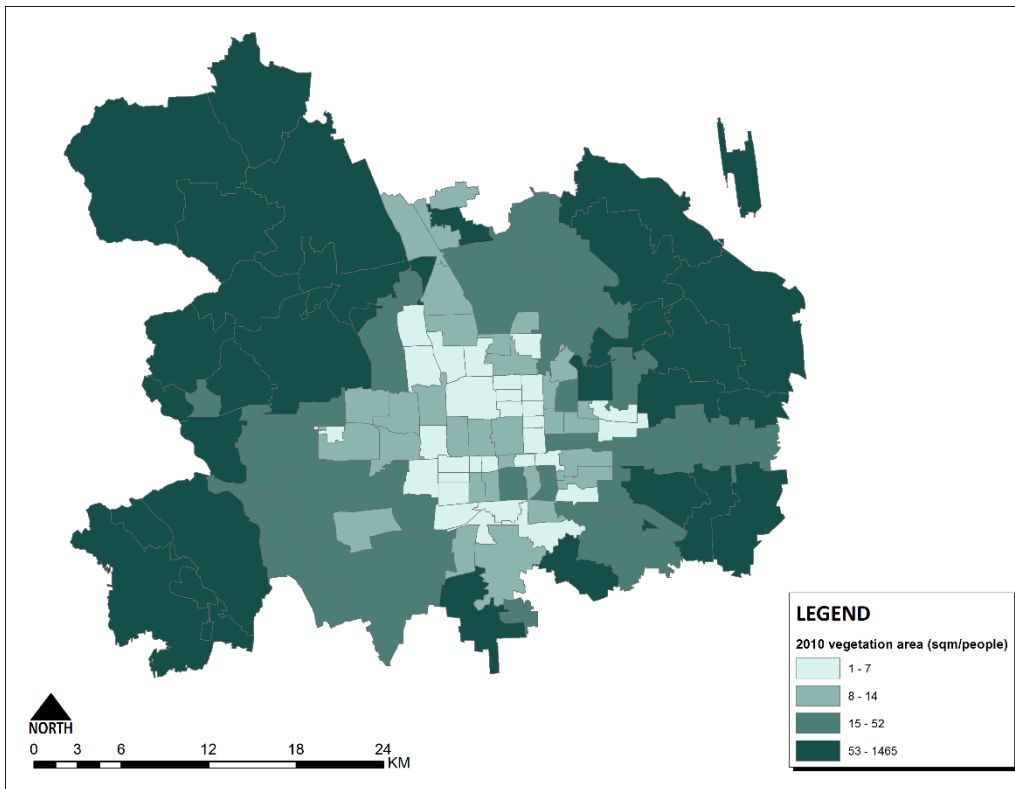


Figure 5-18 Area of vegetation per capita in 2010

5.2.3. Analytical Methods

Similar with the previous section, multiple regression and geographical weighted regression (GWR) are performed to analyze the changes of relations between access to urban green spaces and the socio-economic status at each census tract. Three types of model specifications are used: first model assumes spatial stationarity across the study area; the second model employs a spatial fixed effect specification; the third model employs a spatial lag specification due to the significant spatial autocorrelations have been found (see regression diagnostic in Appendix 8.5).

The formula of OLS is:

$$y = \beta_0 + \sum_{i=1}^n \beta_i x_i + \varepsilon$$

for $i = 1, 2, 3, \dots, n$

where

y : dependent variable (socio-economic status in this case)

β_0 : the intercept

β_i : the coefficient for independent variable x_i

ε : error term

The formula for spatial lag model is:

$$y = \alpha + \beta x + \lambda W_y + e$$

where

α : the intercept

y : the dependent variable (socio-economic status in this case)

W_y : the spatial matrix for y

β : the coefficient for independent variable x

λ : the coefficient for spatial matrix W_y

The formula for spatial error model is:

$$y = \alpha + \beta x + e \quad (e = \lambda W_e + u)$$

where

α : the intercept

y : the dependent variable (socio-economic status in this case)

W_e : the spatial matrix for e

β : the coefficient for independent variable x

λ : the coefficient for spatial matrix W_e

The OLS and fix effect models are conducted in Stata 15 platform. The spatial autocorrelation tests and spatial lag model are performed in Geoda 1.14 Platform.

The formula of GWR is:

$$y_j = \beta_0(u_j, v_j) + \sum_{i=1}^n \beta_i(u_j, v_j)x_{ij} + \varepsilon_j$$

for $i = 1, 2, 3, \dots, n$

where

y_j : dependent variable (socio-economic status in this case)

$\beta_0(u_j, v_j)$: the intercept of location j

$\beta_i(u_j, v_j)$: the local parameter estimator for independent variable x_i at location j

(access to green space in this case)

u_j, v_j : coordinates for each location j

ε_j : error term

Each observation is weighted by using a distance decay function.

Two GWR models are adopted to explore the relationships between (1) change in socio-economic status and change in accessibility to public green spaces, and (2) change in socio-economic status and change in vegetation coverage in each census tract. The GWR is powerful to capture spatial variance of the relationships, which can inform the design and planning interventions. The regressions are conducted via the ArcGIS 10.6.1 (ESRI). An adaptive kernel bandwidth is set to obtain the optimal number of neighbors due to the widely disparate distances of observations in this study. Corrected Akaike information criterion (AICc) is used to determine the optimal value of bandwidth (Fotheringham et al., 2002).

Table 5-1 Statistical description of variables.

No. of Observation 120				
Variables	Mean	S.D.	Min	Max
<i>Dependent Variable</i>				
Change of vegetation cover (m ² per capita)	-56.09	155.8	-749.7	126.5
Change of park access (gravity index in ha)	0.020	0.047	-0.100	0.354
<i>Independent Variable</i>				
Change of employment rate (%)	0.031	0.027	-0.027	0.119
Change of local hukou population (%)	-0.142	0.107	-0.550	0.079
Change of highly educated population (%)	0.167	0.075	-0.033	0.450
Change of living area per capita (m ²)	7.031	6.495	-13.35	30.15

5.3. Results

5.3.1. The Changing Access to Urban Green Spaces

During 2000 and 2010, on average, the access to park green spaces increased by 85.45% and the vegetation coverage per capita increased by 47.49% within the study area.

However, the changes vary spatially. Park accessibility decreased in 28 out of the total 120 census tracts, and they are located in the center and northwest outskirts in *Hai Dian* district (see Figure 5-19). Those census tracts around the 4th Ring Road are major beneficiaries of large-scale afforestation projects, which are concentrated in the north, east, and south plain areas during the decade. Examples include well-known Olympic Forest built for the 2008 Olympic Games and numerous large forest parks converted from agricultural land use in the east and south plain areas. The inner city (within the 2nd Ring Road) has a slight increase of parks through urban renewal projects in forms of pocket gardens and small heritage parks.

Regarding the change of urban vegetation, 47 census tracts experienced a decrease of all types of plants, most of which are located at the periphery (between the 4th and 5th Ring Roads) of Beijing (see Figure 5-20). Due to influx of migrant populations from outside cities and/or provinces, the urban built-up areas expanded beyond the 4th Ring Road into the peripheral areas in the far east of *Chao Yang*, northwest in *Hai Dian*, and southeast in *Feng Tai* district. Unfortunately, the urban development at the cost of consuming agricultural or buffer forest green spaces fails to compensate the loss of vegetation, and thus, lags the increasing demands of growing population. The inner areas (within 4th Ring Road) substitute the loss of agricultural land use with more forest parks.

As a result, although residents increased, the inner areas still can provide more public green spaces in 2010 than 2000.

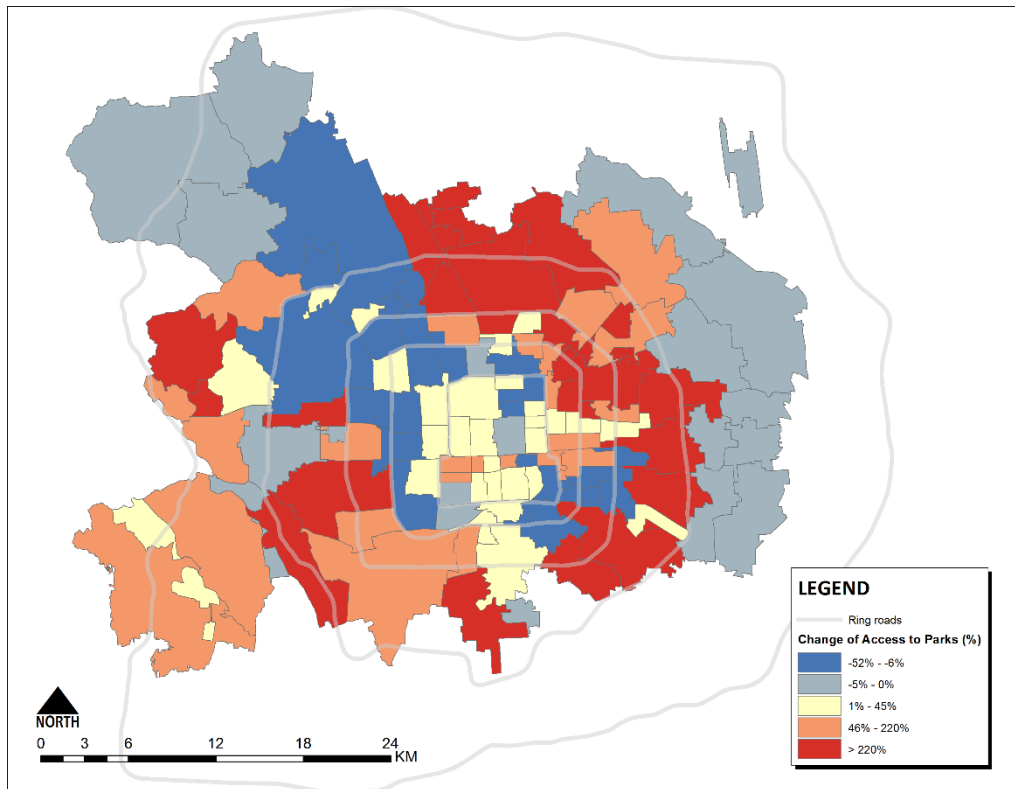


Figure 5-19 The change of access to park green spaces during 2000 and 2010.

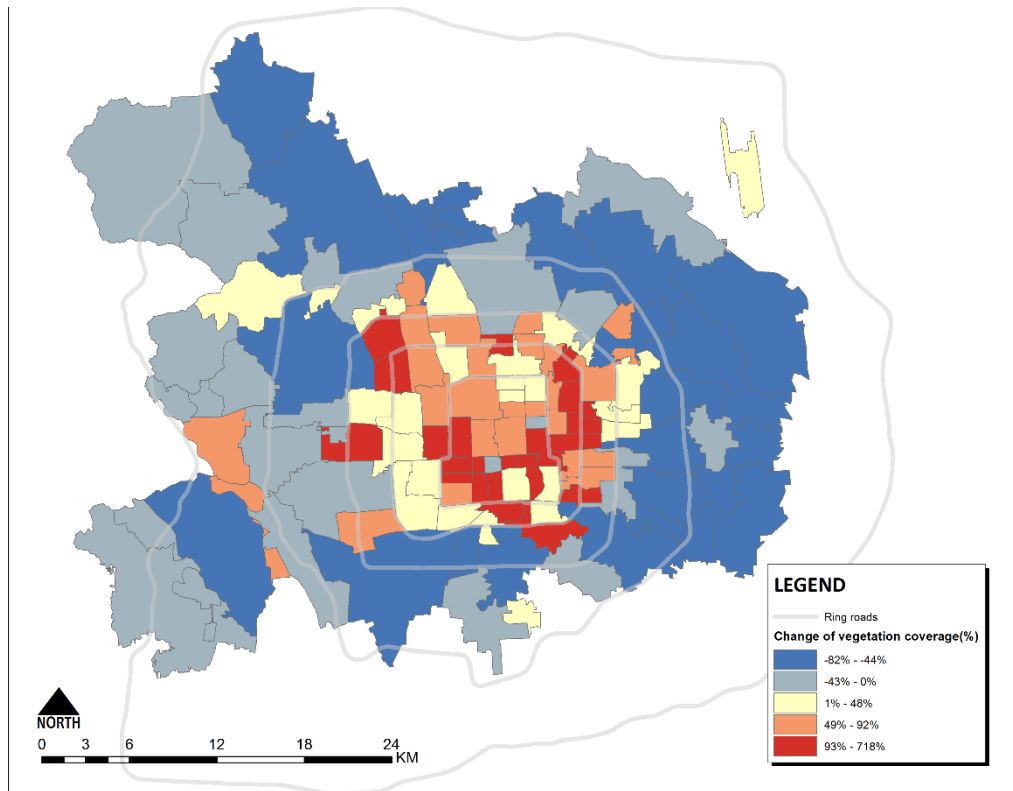


Figure 5-20 The change of urban vegetation coverage during 2000 and 2010.

5.3.2. Global Associations of Green Space Access Changes with Socio-Economic Status Changes

Partially consistent with findings of previous studies in Hangzhou (Wei, 2017), little evidence from these results can prove the afforestation process during 2000 to 2010 exerts deliberate discrimination against socio-economic groups. The bivariate and multiple regressions identified changes of park access are not significantly associated with changes of any socio-economic status (see Table 5-2). Although the spatial lag model (model 6 in Table 5-2) indicates the change of park access is negatively associated with the change in local *Hu Kou* residents but positively associated with the change of the proportion of higher educated population, the model's explanation power is lower than the fixed effect model. The changes of access to overall vegetation—measured by vegetation coverage per capita—are positively related with the changes in employment

rate and proportion of local *Hu Kou* population, while the rest two are not statistically significant (see Table 5-3). Thus, the vegetation coverage tends to favor the advantaged census tracts in Beijing while the park installation does not discriminate the socio-economic groups citywide.

Table 5-2 Regression of access to park change on socio-economic status change.

Variables	Model 1 Park FE	Model 2 Park FE	Model 3 Park FE	Model 4 Park FE	Model 5 Park FE	Model 6 Park LAG
Change of employment	0.1266 (0.2027)				0.0998 (0.2050)	-0.1144 (0.1537)
Change of local hukou		-0.0294 (0.0413)			-0.0428 (0.0425)	-0.0788** (0.0387)
Change of high edu			0.0897 (0.0563)		0.0937 (0.0614)	0.1154** (0.0583)
Change of housing living area				0.0006 (0.0006)	0.0003 (0.0007)	0.0002 (0.0001)
Constant	0.0394*** (0.0085)	0.0367*** (0.0106)	0.0258** (0.0125)	0.0382*** (0.0086)	0.0127 (0.0167)	-0.0135 (0.0128)
Observations	120	120	120	120	120	120
R-squared	0.1314	0.1323	0.1476	0.1340	0.1591	0.1134
Model Specification	FE	FE	FE	FE	FE	LAG

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1;
The VIF values for fixed effect models range from 1.14 to 1.81.

Table 5-3 Regression of vegetation coverage per capita change on socio-economic status change.

Variables	Model 1 Vege FE	Model 2 Vege FE	Model 3 Vege FE	Model 4 Vege FE	Model 5 Vege FE	Model 6 Vege LAG
Change of employment	1,068 (685.1)				1,365.46** (585.28)	747.54** (373.78)
Change of local hukou		807.4*** (118.9)			841.84*** (121.24)	568.38*** (98.33)
Change of high edu			186.6 (193.3)		-112.90 (175.23)	-100.47 (140.14)
Change of living area				-0.03 (2.19)	0.86 (1.93)	1.99 (1.59)
Constant	-117.9*** (28.83)	60.46* (30.63)	-127.7*** (43.03)	-93.24*** (29.56)	49.91 (47.64)	36.54 (30.52)
Observations	120	120	120	120	120	120
R-squared	0.086	0.337	0.074	0.066	0.3686	0.533
Model Specification	FE	FE	FE	FE	FE	LAG

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1;
The VIF values for fixed effect models range from 1.14 to 1.81.

5.3.3. Local Variance of Relationships Between Green Space Access Changes with Socio-economic Status Changes

The GWR results are overlaid with the changes of each socio-economic indicators to show the pattern of local relations:

5.3.3.1. Changes of Employment Rate and Park Accessibility

A few periphery Townships from *Chao Yang*, *Feng Tai*, *Hai Dian*, and *Shi Jing Shan* Districts show a decline in employment rate (shaded as red), but those in *Feng Tai* District (southwest part of Beijing) and *Chao Yang* District have increased access to park and public green spaces given the negative local relationships (see Figure 5-21). Majority of Townships experienced a rise of employment rate while their changes to park accessibility vary in terms of direction. The suburb Townships in the south, north, and east areas experienced increases of employment rate but lose their access to parks. Conversely, the northwest part of city is observed both increment of employment rate and parks. Such contrasting pattern indicates the south and east areas, although manage to install many parks, they seem falling behind the growth of population comparing with the northwest counterparts.

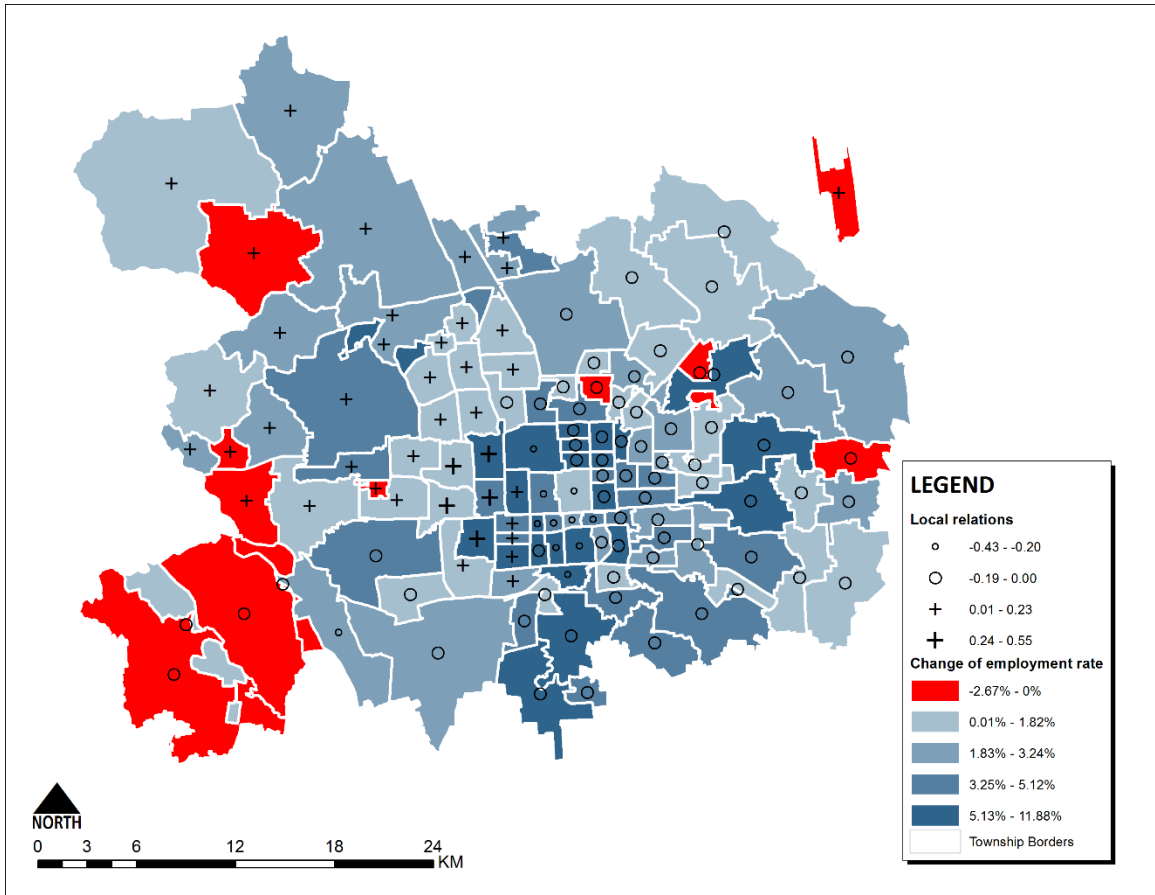


Figure 5-21 Local relationships between employment rate change and park access change.

5.3.3.2. Changes of Employment Rate and Vegetation Coverage

Those periphery Townships from *Chao Yang, Feng Tai, Hai Dian, and Shi Jing Shan* Districts with declines in employment rate experience vegetation drops (see Figure 5-22), although most of them have park accessibility increased (see Figure 5-21). Comparing with the changes of park accessibility, the Townships in the south, northwest periphery, and east areas experienced both increases employment rate and vegetation coverage, and the northwest areas—where universities aggregate—seem to lose vegetations yet gain more employed population.

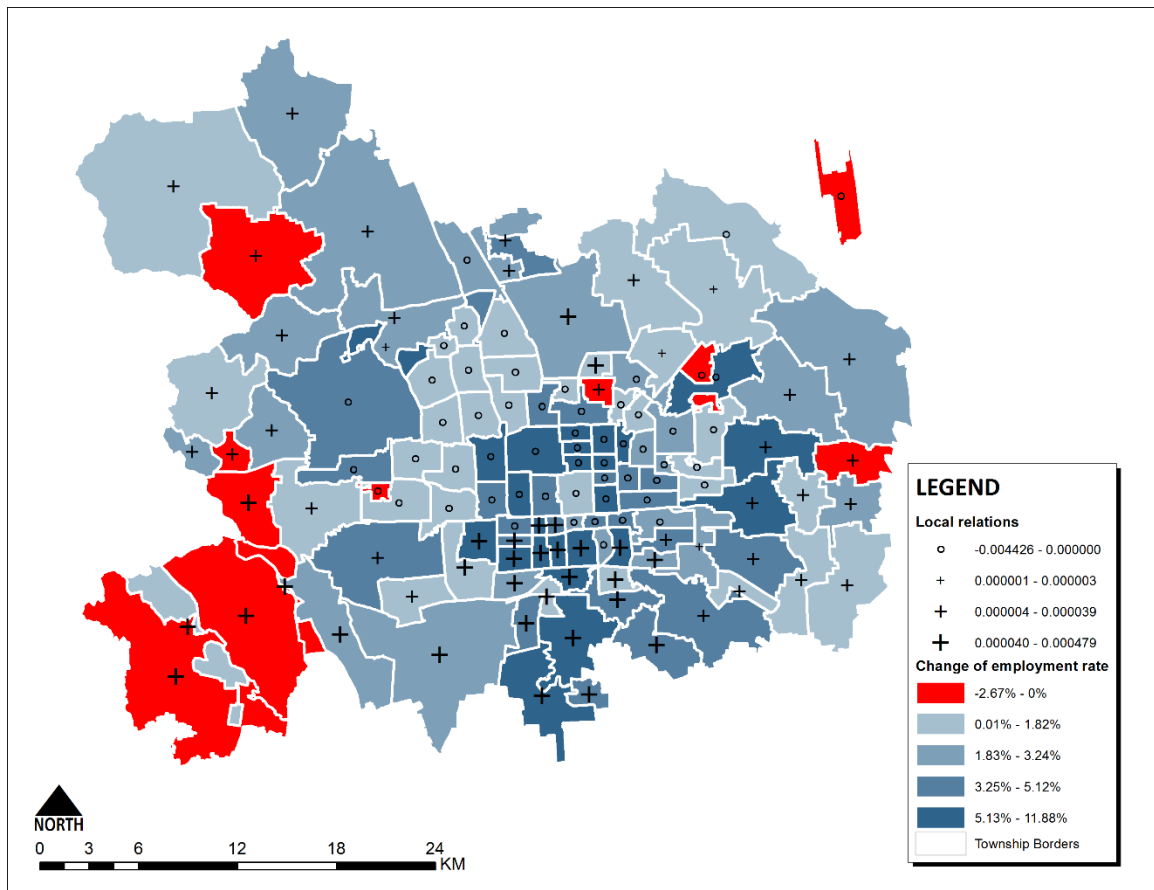


Figure 5-22 Local relationships between employment rate change and vegetation coverage change.

5.3.3.3. Changes of Highly Educated Population and Park Accessibility

Percentage of highly educated population significantly plunged in only two census tracts in the northern and southern suburbs of *Hai Dian* and *Feng Tai* Districts respectively (see Figure 5-23), while their accesses to parks are decreased. The rest Townships largely increase the higher education level of their populations whilst growth in accessibility to parks due to the positive local relationships observed. The highest magnitude of park accessibility increases is found in the north Olympic Forest Park, southwest suburb, and the east CBD region. The old city (within 2nd ring road) also has increased both park access and education level.

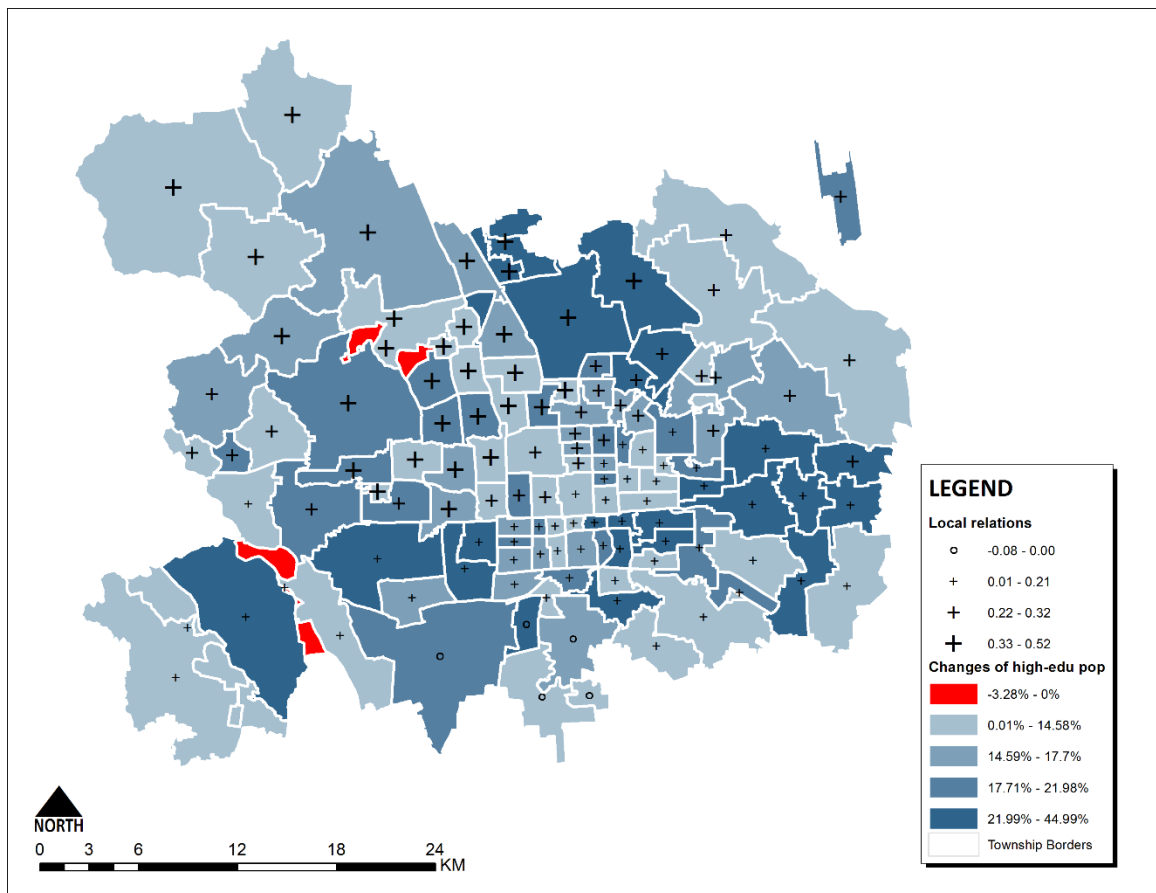


Figure 5-23 Local relationships between education level change and park access change.

5.3.3.4. Changes of Highly Educated Population and Vegetation Coverage

Areas that lose more higher educated population are treated by more vegetation in the two tracts shaded with red color (see Figure 5-24). The trend of changes in vegetation coverage in rest of Township tracts is similar with park accessibility except the central city and northwestern mountainous areas, where local relations show a negative direction indicating their education levels increase but vegetation coverages decline. These areas failed to provide equal regulating services by losing total vegetation coverage comparing with the east, north, and south parts of city. The old city (within 2nd ring road) has increased education level but the vegetation coverage is decreased. This is possibly people in the old city Township tract can access parks in neighboring tracts while the vegetation in their own tracts decline.

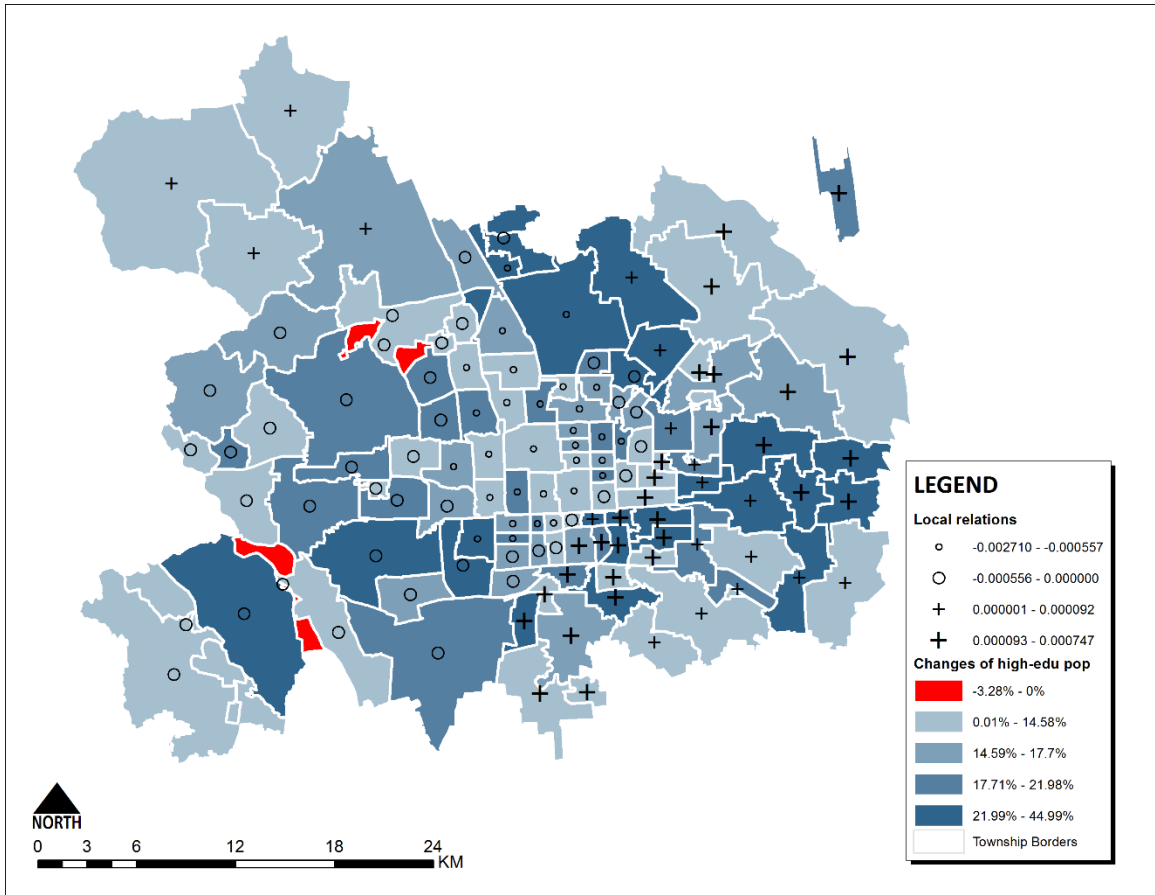


Figure 5-24 Local relationships between education level change and vegetation coverage change.

5.3.3.5. Changes of Local *Hu Kou* Population and Park Accessibility

Most of Township tract experienced a drop in local *Hu Kou* population, which means the city is gaining more migrant residents from outside. Although decrease of local *Hu Kou* population—the flux of less advantaged migrant people—is commonly found at the east and northwest suburb tracts of Beijing (see Figure 5-25), these suburban areas are treated with more public green spaces in the past decades. On the contrary, increased migrant workers living in the central cities and education zone in the northwest are unable to access more parks than those in the suburbs. Townships in *Feng Tai* District, though declined in percentage of migrant workers, their access to parks are increased more than other Townships in the city.

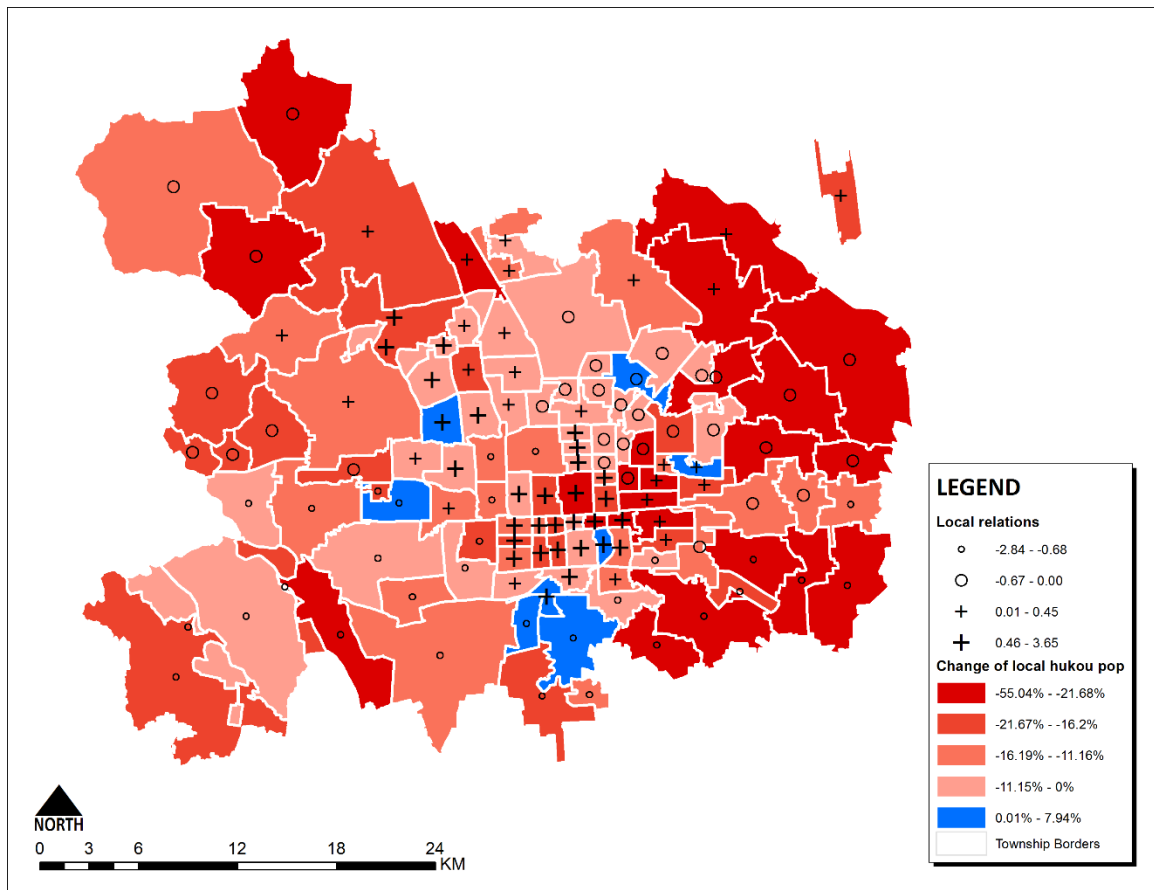


Figure 5-25 Local relationships between local hukou population change and park access change.

5.3.3.6. Changes of Local *Hu Kou* Population and Vegetation Coverage

With a massive influx of non-local *Hu Kou* population in the eastern and northern peripheral areas of the city, the total vegetation coverages are encroached for the sake of accommodating more residents through urbanizing agricultural and forest lands (see Figure 5-26). Again, the most Townships in *Feng Tai* District, though received similar volume of migrant workers, provide more vegetation coverage than other Townships in the city.

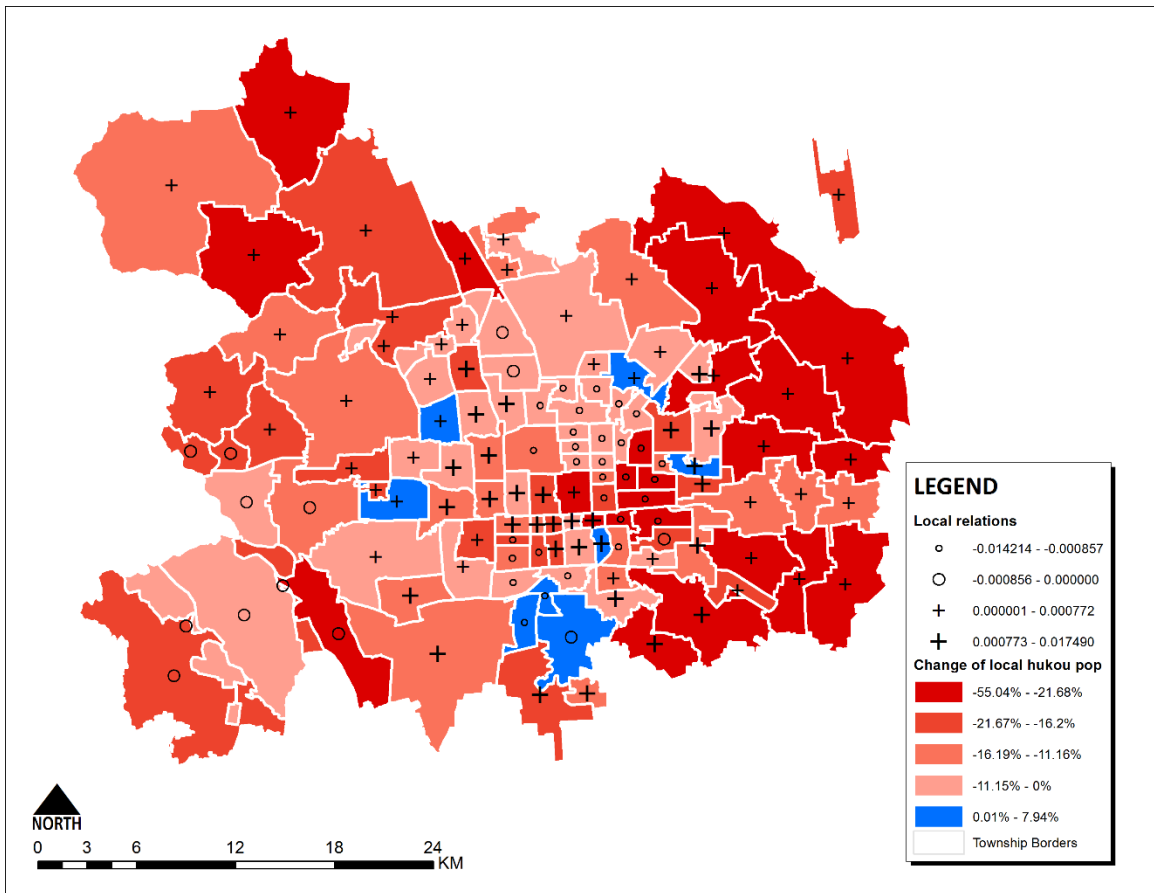


Figure 5-26 Local relationships between local *Hu Kou* population change and vegetation coverage change.

5.3.3.7. Changes of Living Area per capita and Park Accessibility

Finally, residents both in the central city and suburban areas live in bigger houses in 2010 than 2000 except some suburban Township tracts where average living area per capita is dropped (shaded in red) (see Figure 5-27). Their accesses to public green spaces are similar in the Townships with an increased living area—the more areas of housing, the higher access to parks (see Figure 5-27). People living in the south and east parts gain smaller areas of living space with less access to parks comparing with those in north and northwest who living in bigger house and having more parks around. Those experienced drops in living areas are also losing access to parks—the magnitude is stronger in the south and east suburbs. It might be that the government use more parks to replace existing villages that provide larger living areas.

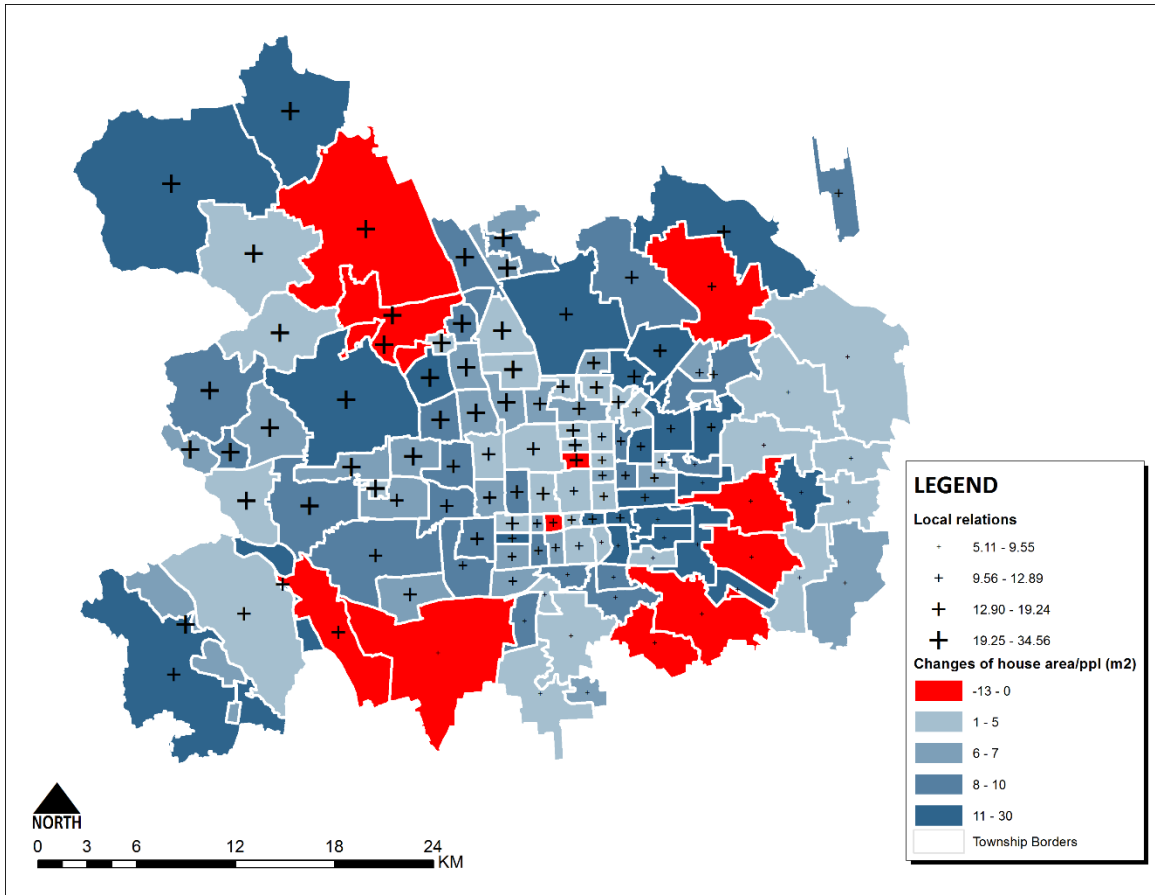


Figure 5-27 Local relationships between changes of living area per capita and park access.

5.3.3.8. Changes of Living Area per capita and Vegetation Coverage

Township tracts that are becoming denser—showing a declining housing area per capita—are benefiting more from regulating services of increased vegetation only if they are in the northern parts of the *Hai Dian* District (see Figure 5-28). Those who dwell in the suburb of *Chao Yang* District are deprived of both living areas and vegetation volumes around their neighborhoods (see Figure 5-28). People living in the south and east parts gain smaller areas of living space with less coverage of vegetation, while those in north and northwest who living in bigger house and having less vegetation coverage but more parks around.

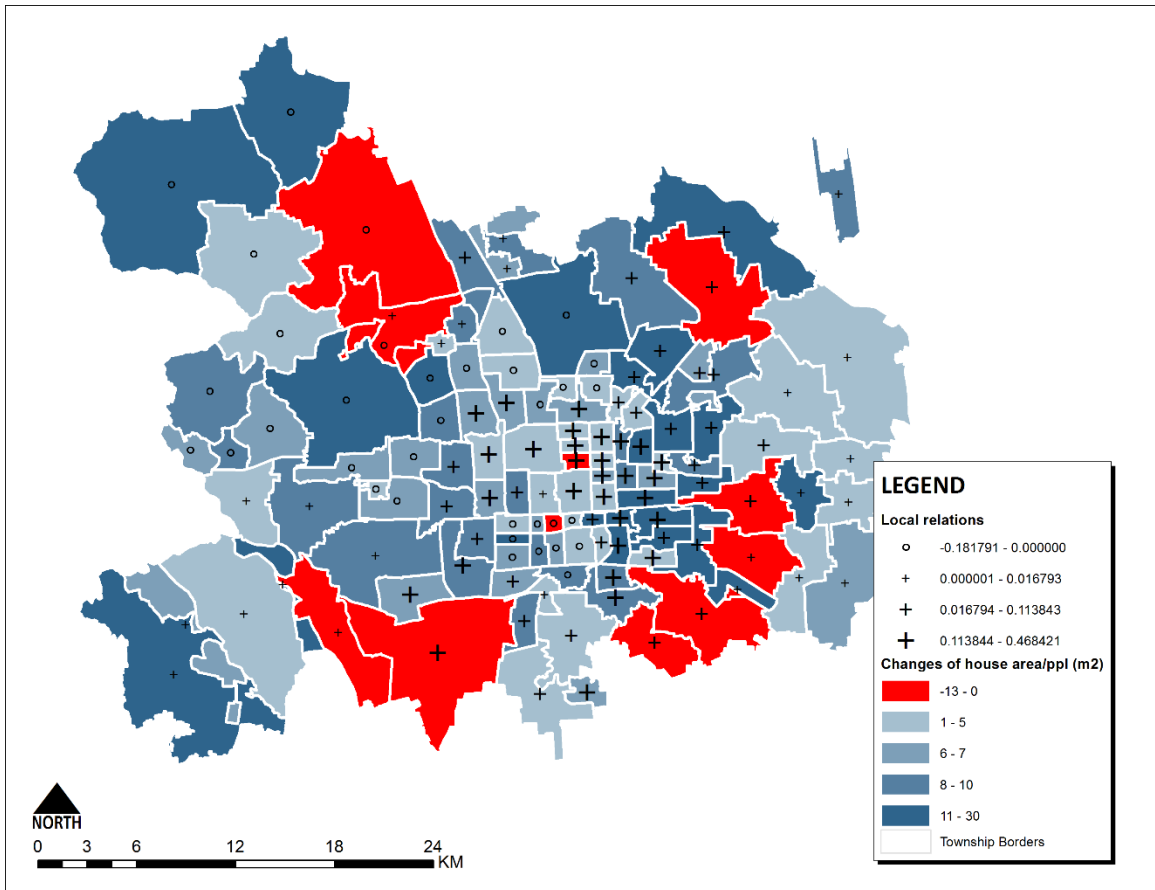


Figure 5-28 Local relationships between changes of living area per capita and vegetation coverage.

5.4. Discussions

Although the green spaces increased significantly during 2000 and 2010, the global regression did not identify major differences of the changes of green spaces between socio-economic groups. Little evidence can be found that changes of park accessibility level relate to changes of socio-economic statuses during afforestation in 2000 and 2010. In terms of vegetation changes, the only statistically significant results are associated with the socio-economic changes measured by local *Hu Kou* population and education level. And the estimation values are both positive showing that increases in vegetation is associated with the increase individuals with local *Hu Kou* and higher education, i.e. more advantaged social groups. The Geographically Weighted Regression identified inconsistent relationships between the changes of green spaces and socio-economic statuses.

5.4.1. Changes of Employment Rate and Urban Green Space

Between 2000 and 2010, peripheral townships of Beijing have mostly experienced increased rates of employment, except for some farther suburbs such as *Feng Tai* and *Chao Yang* districts (see red shaded Figure 5-21). Interestingly, these suburban townships in *Feng Tai* and *Chao Yang* received more volume of parks than the other peripheral townships with increased employment rates, which seems to indicate the implementation of parks favors less-employed census units (Township). This is possibly due to the massive addition of large parks such as the *Yuan Bo Yuan* (Beijing Garden Exposition Park) in *Feng Tai* and the *Chao Yang* Park and other large natural parks in the *Chao Yang* district. It might also be possible that the construction of massive parks is

achieved by reclamation of farmland that dismantles urban villages, turning farmers to unemployed urban residents and causing decreased employment rates.

The employment rates in southern and eastern townships have increased between 2000 and 2010, while access to parks in these areas has decreased, indicating that park implementation lags behind socio-economic development. The northwest subdistricts, mostly surrounded by royal gardens and palaces in *Hai Dian*, also displayed a rise in employment rate during this period, but access to parks also increased in these areas. This suggests that addition of parks tend to build upon and benefit from existing heritage gardens, differing from southern and eastern subdistricts, which lack historically present public green spaces.

Regarding changes in vegetation, the townships with a decline in employment rate between 2000 and 2010 also suffered from reduction of all types of vegetation. One possible explanation is that the abovementioned large park installations in these areas replaced other forms of vegetation (buffer forests or farms) but failed to compensate for the total loss of vegetation, diminishing the level of regulating services. The townships in the farther southern, eastern, and northwestern areas of the city all have an increased vegetation volume as well as a rising employment rate. Such significant addition of vegetation volume might come from the 2nd “Green Belt” or tree planting projects of farmlands. Inner city townships, particularly within the 2nd Ring Roads and northern 3rd Ring Roads are losing vegetation due to intensive urban development that often occupies existing green space (for example the 1st “Green Belt”) or farmland.

5.4.2. Changes of Highly Educated Population and Urban Green Space

The majority of townships in Beijing gained both highly educated populations and access to parks between 2000 and 2010. The highest magnitude of park accessibility increase is found in the northern Olympic Forest Park, southwestern suburbs, and the eastern Central Business District in *Chao Yang*. These are mostly the results of event-driven urban development integrating large scale parks in urban schemes, including the Olympic Parks, *Feng Tai* Expo Garden, and some industrial subcenters in Beijing. Some southern suburban townships in *Feng Tai* show a reduction of park accessibility. This might suggest the park amenities failed to catchup to the growth of socio-economic status in the population of southern Beijing.

The changes of vegetation and the relationships to education level show a different pattern. The north and northwest townships in *Hai Dian* and *Feng Tai* dismantled the total vegetation areas such as farmland for urban development to attract and accommodate more highly educated people. Some inner area townships in the *Xi Cheng* and *Dong Cheng* districts within the 2nd Ring Road also went through such reduction of vegetation but were subject to the continuous densification of inner-city areas, leaving little space for planting more trees. The east areas in *Chao Yang* seem to provide sufficient urban vegetation to accommodate the growth of highly educated population.

5.4.3. Changes of Local *Hu Kou* Population and Urban Green Space

As the city attracts more migrants from outside, the local *Hu Kou* population drops in most townships. In the east and south townships, both the park accessibility and marginalized people (nonlocal *Hu Kou*) increase. Yet, in the central and northwest

townships, the growth of non-local *Hu Kou* population has outpaced the addition of parks. This pattern proves that east and south plain area townships at the periphery have more potential spaces for creating parks than those at the foothills, although the latter already has abundant historical parks in an almost fully built-up city center.

With the exception of the townships in southwest *Feng Tai* on the outskirts and *Dong Cheng* in the center old city (within the 2nd Ring Road), most townships have dropped vegetation volume. Those on the outskirts with a decrease of both vegetation and local *Hu Kou* (advantaged groups) often consumes large agricultural lands for urbanization. But the level of vegetation increment in the built urban areas—mostly parks—is still much lower than the influx of marginalized people (measured by *Hu Kou* status). The inner-city area, on the other, particularly the south part of *Xi Cheng* and *Dong Cheng* as well as *Hai Dian* district simply have little spaces to add more vegetations for providing regulating benefits to the growing marginalized population.

5.4.4. Changes of Living Area per capita and Urban Green Space

Between 2000 and 2010, the size of housing units has increased as has access to parks. However, living space and access to parks have decreased in some periphery townships. To add more parks, some “Urban Villages”, which are a source of affordable housing for lower income population, are required to be removed. In other words, the reduction of affordable housing areas is attributable to making more rooms for park projects. This evidence might be in the *Feng Tai* Garden Expo and some forest parks in suburb *Chao Yang* and *Hai Dian* districts.

In the north and west of Beijing, the townships with increased area of housing per capita have reduced volume of vegetation at vicinity. In the center and east, the townships increased both the vegetation volume and living area. This contrasting pattern might be related to the topographical constraints in Beijing, where north and west hilly areas have less developable spaces than the east and south plains for both housing related projects and urban afforestation. And the housing projects are often prioritized leaving fewer rooms for urban green spaces.

5.5. Summary of Section 5

This section investigates the trend of changing accessibility to urban green space in different socio-economic groups between the years 2000 and 2010. Although green spaces increased significantly during the period, the global regression estimation did not identify significant associations between the changes of green spaces and the socio-economic statuses in Township (census tract unit). Little evidence can be found that park implementation favors or discriminates any marginalized groups. In terms of vegetation changes, the only statistically significant results relate to the socio-economic changes measured by local *Hu Kou* population and employment rate. For these studies, the estimation coefficients are both positive, showing that increases in vegetation are associated with the increase of census tract with higher proportion of local *Hu Kou* and higher employment, i.e. more advantaged social groups. The Geographically Weighted Regression identified inconsistent relationships between the changes of green space accessibility and socio-economic statuses. Potential factors causing the variances of local relationships between the changes of green space accessibilities and socio-economic statuses are illustrated and discussed.

6. The “Green Paradox”

The previous sections showed that spatial discrepancies in access to public green spaces exist, and afforestation in Beijing in terms of providing public green spaces tends to serve marginalized groups more. Such patterns are attributable to the continuous efforts of investment in green spaces by the Beijing Municipality in the most recent decade, as well as the factors of geographical constraint, historical legacies, urban planning, and funding mechanisms of urban green space projects. However, during the afforestation process, the efforts to address environmental inequality might lead to some unpleasant alterations in socio-spatial patterns due to such factors as gentrification, segregation, and dislocation effects that come along with green space installations. This section focuses on such concerns and aims to identify if adding green spaces results in the gentrification of neighboring areas, thereby dislocating lower social groups who can no longer afford living in such areas due to the cost increase stemming from improved environmental quality. If such a trend is observed, the marginalized groups are excluded from benefiting from afforestation projects which are ostensibly equally accessible.

The following questions will be addressed in this section:

- Does adding new green space gentrify the neighboring communities in Beijing, thus resulting in the dislocation of marginalized groups? And if so, to what extent?
- What are the features and types of new green spaces attributable to gentrification?
- What planning approaches and policies are responsible for green space-associated gentrification?

6.1. Introduction

Evidence from previous sections indicate that the afforestation process does not distinguish different socio-economic groups and the government's efforts tend to benefit more marginalized groups in terms of green space accessibility. But the controversial outcomes driven by such environmental changes are subject to scrutiny. Public green spaces are known to impact housing sales prices, which has been confirmed by many previous studies (Anguelovski et al., 2017; Crompton, 2005; Czembrowski & Kronenberg, 2016; Kong et al., 2007; Pandit, Polyakov, Tapsuwan, & Moran, 2013; Wolch et al., 2014). Therefore, it is plausible that newly added public green spaces contribute to housing sales price increases in their vicinity which are not affordable for less wealthy groups, hence resulting in the gentrification of that neighborhood. The higher housing prices and subsequent increase in wealth residents attracts better amenities (e.g. high-end stores and restaurants), and in turn, this attracts more advantaged groups in a kind of snowball effect (Zheng & Kahn, 2013). Without proper planning and subsidy regulations, the public green spaces that should be accessible to most of the residents in a given area wind up serving only a limited group of wealthy people because of this "green gentrification".

In contrast to previous research on green space-associated gentrification, this section intends to provide two original contributions. The first is a city-wide investigation to be conducted in order to gain a holistic understanding of green space-associated gentrification in the largest developing economy, China. Second, current researchers tend to construe urban green spaces such as park or public green spaces in an overly broad manner, which hinders their ability to explain the multiple benefits that green spaces

have. In fact, public green spaces with different features or types deliver various distinct benefits. For instance, a cemetery or vacant green space might be less appreciated than forest parks or wetlands by residents because of different recreation amenities. These features of green space can be perceived by neighboring residents and so might have different levels of association with housing prices (Panduro & Veie, 2013). Thus, this study attempts to discern different features and types of public green space that might be responsible for gentrification.

6.2. Data and Method

6.2.1. What is Green Space-Associated Gentrification?

Generally, green space that is associated with gentrification comes in two forms in China (see Figure 6-1). One is associated with green space involved in the “city beautification” movement, which renovates and redevelops dilapidated environments in city centers. These reforestation projects tend to improve the environmental qualities in surrounding neighborhoods and are often reflected in the surrounding housing costs—an effective signal of gentrification. The other, second effect, has to do with the relocation of original residents for green space installation (Zheng & Kahn, 2013). Urban reforestation projects on the urban outskirts require large areas of land to install and therefore low-cost agricultural or village lands are preferred by developers. The villages providing inexpensive and “affordable” rental housing units—commonly known as “Urban Villages”—tend to be replaced by more expensive commercial residential quarters, not affordable to the poor. The increased housing cost dislocates those less well-paid groups, forcing them into cheap and low-quality communities that are often much further from the original locations; while improved living conditions attract more advantaged groups replacing the existing marginalized residents.

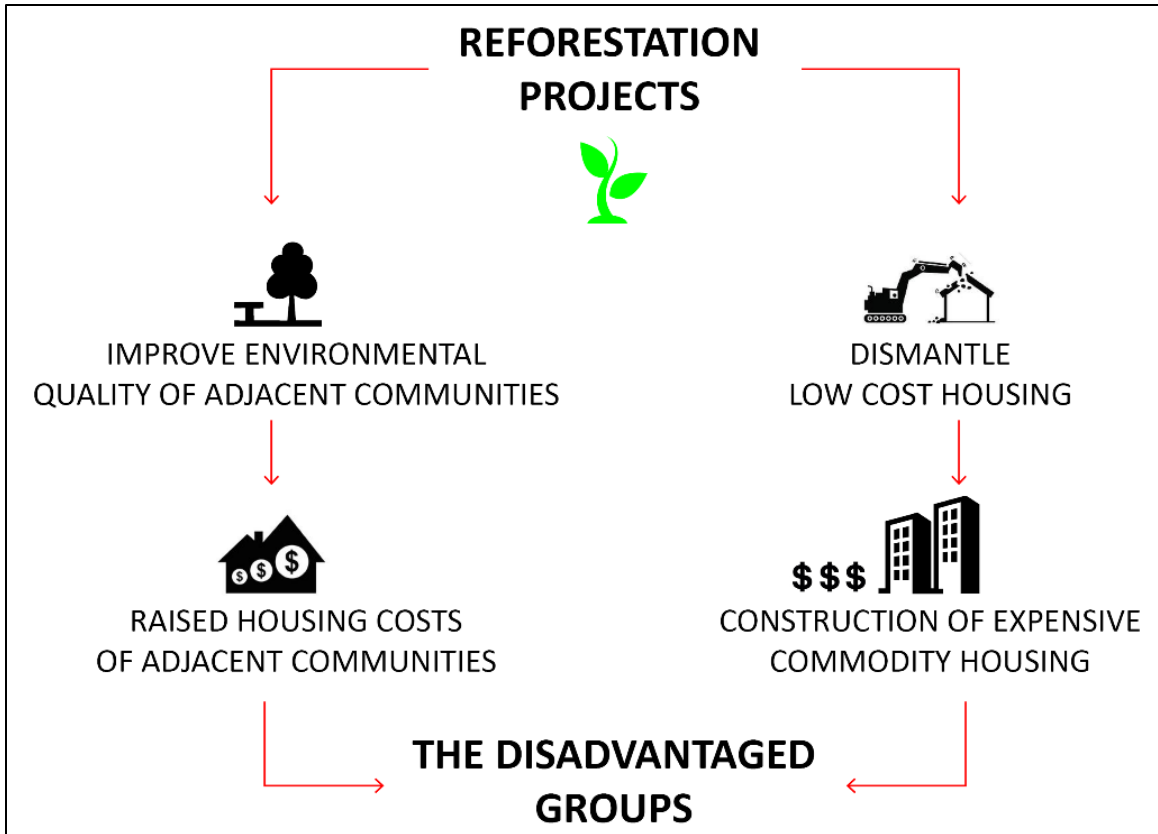


Figure 6-1 Mechanism of green space related gentrification in Beijing.

6.2.2. How to Identify the Gentrification Effect

Studies on the effects of gentrification often combine multiple indicators to avoid over-simplification (Anguelovski et al., 2017; Bostic & Martin, 2016). However, the changes in economic status and demographic structure data cannot fully explain the causal relationship between an increase in urban green space and gentrification. This data does not neutralize natural economic increases of a study area. Therefore, housing sales prices were adopted in many studies to better observe green gentrification as an additional indicator (Anguelovski et al., 2017; Yasumoto et al., 2014; Zheng & Kahn, 2013). By investigating changes in structural patterns of housing prices due to green space changes, the mediation effect of green space can be seen as signaling gentrification

effects. Another reason to adopt housing price as an indicator of gentrification is that housing sales price is the only data available during 2011 and 2018 in Beijing.

6.2.3. Hedonic Pricing Model with A Difference-In-Difference Estimator

The Hedonic Pricing Model is an economic method that can account for prices of goods or services (Czembrowski & Kronenberg, 2016; Kong et al., 2007). The transaction of sold houses with structural information from 2011 to 2018 and the access to neighborhood amenities and green spaces will be used to construct the formation of the hedonic model in this study. Researchers using the hedonic pricing model often confront spatial auto-correlation issues, which might lead to inaccurate results (Basu & Thibodeau, 1998). This is because the housing sales price is influenced by neighborhood property prices (Czembrowski & Kronenberg, 2016). One way to mitigate spatial auto-correlation is to adopt a spatial fix effect or spatial lag/error model. The total housing price is logged due to nonlinearity in this section.

This section also involved a difference-in-difference estimator based on previous research (Pope & Pope, 2015) to measure whether newly constructed urban green space has an impact on housing prices. The study set treated groups as those within 500m from a closest new urban green space and control groups are those located between 500m and 3,000m from a closest new urban green space. The threshold distance of 500m is determined by previous studies (Crompton, 2005; Panduro & Veie, 2013). In Beijing, a buffer distance of 500m is one common measurement of urban green space planning evaluation by official sectors (Capital Greening Office, 2010). A preliminary test using the data of this study also confirmed that green spaces positively influence housing prices within 500m in this case. To further distinguish the strengthen of green spaces' impact on

housing price, the Hedonic Pricing Model includes distance dummy interacting with post-green transaction based on 100m interval. The multicollinearity of involved variables is checked with VIF values ranging from 1.01 to 2.08 indicating there is no evidence collinearity. All the regressions are conducted in Stata 15.

The formation is shown below:

$$\ln(P) = \beta_0 + \beta_{11}H + \beta_{12}N + DistYr + \sum_{gs} [(\beta_1 * D_{gs}^{0.1} + \beta_2 * D_{gs}^{0.2} + \beta_3 * D_{gs}^{0.3} + \beta_4 * D_{gs}^{0.4} + \beta_5 * D_{gs}^{0.5}) + (\beta_6 * D_{gs}^{0.1} + \beta_7 * D_{gs}^{0.2} + \beta_8 * D_{gs}^{0.3} + \beta_9 * D_{gs}^{0.4} + \beta_{10} * D_{gs}^{0.5}) * Post_{gs}] + \varepsilon$$

Where

$\ln(P)$: the log of total housing transaction price;

$D_{gs}^{0.1}, D_{gs}^{0.2}, D_{gs}^{0.3}, D_{gs}^{0.4}$, and $D_{gs}^{0.5}$: indicators of a property located within distances of 100m, 100-200m, 200-300m, 300-400m, and 400-500m from the closest public green space respectively;

$Post_{gs}$: an indicator whether a transaction has happened after installation of new green spaces. The subscript gs stands for types of urban green space;

H : the housing structural variables;

N : non-greenspace associated neighborhood amenity;

$DistYr$: the district and year fixed effects;

ε : an error term.

The falsification and graph analysis for testing difference-in-differences identification strategy are conducted. The results support the interpretation of a causal relationship that adding green spaces increase the housing sales price at the vicinity. See detailed analyses and reports in Appendix 8.6 and 8.7.

6.2.4. Type, Feature, and Access to Urban Green Spaces

The study investigates the park green spaces, which are accessible to the public. The number of parks and their geolocations come from the Beijing Municipal Bureau of Greening and Gardening (Capital Greening Office, 2018). There are a total 315 registered park green spaces as of the year 2018 (Capital Greening Office, 2018). The border and built year of a given park's green spaces are identified based on historical maps from Google Earth (see Figure 6-3). All the green space data went through a double-check process by the author for ensuring accuracy. Although the Chinese Standard for Classification of Urban Green Space defined the urban green space according to functionality and land use, the classification categories often overlap, and the official map of park classification in Beijing is not available. More importantly, the official classification system does not consider the public's perception, which might be an influence when buying a house (Panduro & Veie, 2013). Therefore, based on the official standard and previous studies on green spaces' premium effect on housing sales prices (Czembrowski & Kronenberg, 2016; Kong et al., 2007), this study reclassified urban green space into four types: Comprehensive Parks, Natural Parks, Theme Parks, and Historical Parks.

Comprehensive Parks (see Figure 6-2) provide multiple recreational facilities for the public. The parks have a large component of well-maintained vegetation as well as

diverse leisure facilities and spaces. Most of them were built after the establishment of the PRC (Beijing Local Chronicles Compilation Committee, 2000).

Natural Parks (see Figure 6-2), also called Countryside Parks, are commonly located at the periphery of the city to serve ecological preservation purposes and provide space for leisure activities (Capital Greening Office, 2012). They often have larger areas of natural vegetation with a small portion of artificial plants which require less maintenance. The construction of natural parks involves fully using existing vegetation such as agricultural crops, buffer forests, and/or other vernacular plants.

Theme Parks (see Figure 6-2) present specific programs or purposes for outdoor activities such as zoos, botanical gardens, sports, and amusement facilities. There is a high entry fee to access a theme park (e.g. 120 CNY for Beijing Amusement Park). The green space coverage ratio of certain theme park—typically those for amusement purpose—is often lower than the other three types for the purpose of leaving more spaces for entertaining facilities.

Historical Parks (see Figure 6-2) are those bear high historical value. Many of Beijing's parks and green spaces were royal palaces, such as the Summer Palace, or renovated from ancient defensive walls or moats, such as the *Yuan* Dynasty City Wall Relics Park was spring from the moat of *Yuan Da Du* (Capital of *Yuan* Dynasty). These heritage parks, rich in historical value, may be attractive to homebuyers (Moro, Mayor, Lyons, & Tol, 2013). The official descriptions of Capital Greening Office, as well as

consultation from professionals²¹ participated in the design of a specific historic site, can be used to determine the status of an urban green space as an historical heritage park.

In addition to the area and type, the study differentiated quality of parks to discern the effect on housing price. Two general indexes are adopted: one is vegetation coverage ratio calculated via the total area of all types of vegetation divided by total area of a park; the second relies on average value of Normalized Difference Vegetation Index (NDVI) as a gauge for the quality of plants. The NDVI is calculated using growing season remote satellite images (sentinel 2) from the European Space Agency (ESA) by setting value of 0.3 as a threshold.

Given the confirmed environmental externality of waterbody features in urban settings (W. Y. Chen, 2017; van Dijk, Siber, Brouwer, Logar, & Sanadgol, 2016), this study also includes water bodies as predominate features of urban green spaces. The presence of water is recorded by manually examining the site with a high-resolution satellite map from Google Earth.

In terms of measuring the access to urban green spaces, the study calculated the linear distance from one housing property to the boundary of the closest green spaces. Although scholars mentioned that using street networks might better reflect realistic walking distances (Higgs et al., 2012), the detailed road network in each given year is not available. This section does not include the change of total volumes of green spaces within each gated community because the green space coverage of the residential quarter remained unchanged in most cases.

²¹ Conversation with Lei Wang, project manager of Bei Lin Di Jing Landscape Design and Planning, 2018

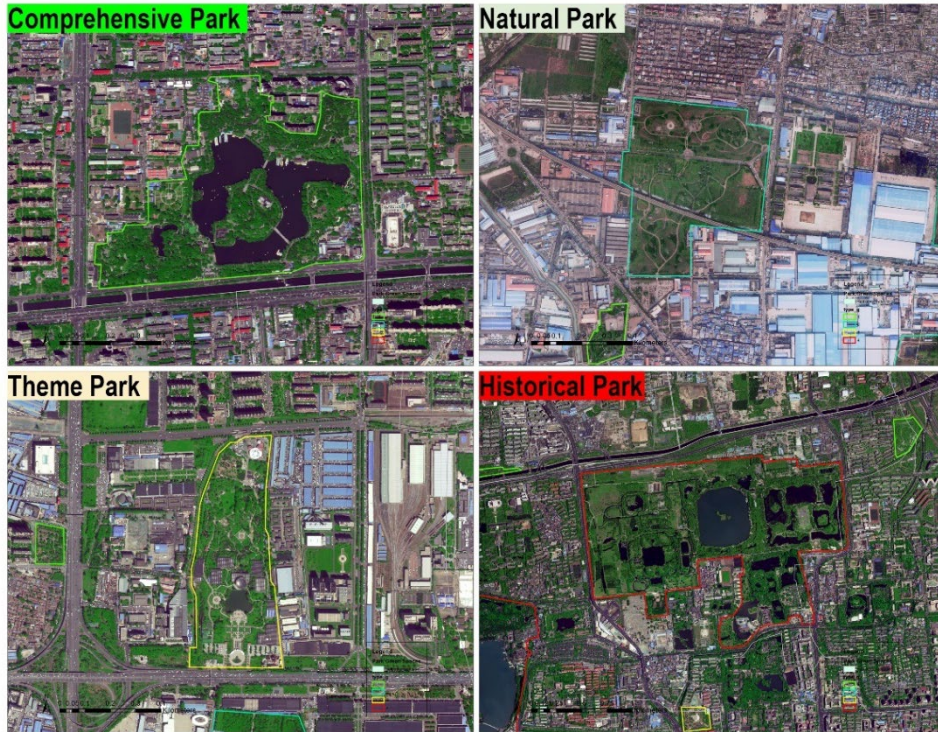


Figure 6-2 Examples of four types of green space in this study: Comprehensive Park (top-left); Natural Park (top-right); Theme Park (bottom-left); Historical Park (bottom-right). Author drawn based on Google Earth, Gaode Map, and Capital Greening Office, 2018.

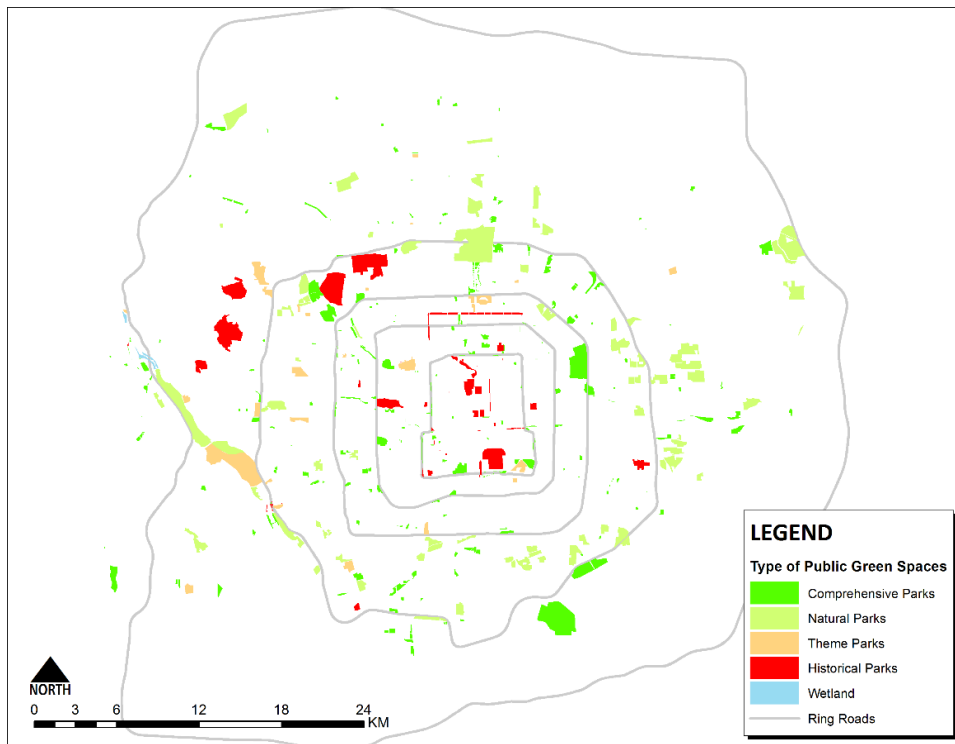


Figure 6-3 Type and distribution of park green spaces. Author drawn based on Google Earth, Gaode Map, and Capital Greening Office, 2018.

6.2.5. Housing Transaction Data and Structural Variables

The transition of housing markets and an accumulated large housing sales data scale provides opportunities to conduct this study. In the late 1990s, the Chinese residential housing market turned into a freer one, making it possible to apply the hedonic pricing model to quantify the monetary value of public green spaces (Kong et al., 2007). While Beijing is struggling to add public green spaces since the Olympic event in 2008, the commercial housing market is entering a “second-hand housing era”, that is, more resold houses than new ones. The rapid growth of the second-hand housing market and private brokerage industry accumulated large numbers of detailed transaction data across the entire built-up area of Beijing. Thus, second-hand commercial housing sales will be a feasible index to identify the phenomenon of green gentrification at a city scale.

The housing transaction data involved in this study is extracted from one of the largest brokerage companies: Lianjia²². The company provides valid open source data of real transactions of resold commercial housing property with detailed structural features²³. The total number of 301,090 housing transactions that happened during the years 2011 to 2018 are extracted and processed, and each property is georeferenced, relying on address searching services from Gaode Map (see Figure 6-4 & Figure 6-5). A total number of 49,502 housing transactions whose closest distance is within 3000m from a newly built green space are extracted for the model (see Figure 6-6).

The housing data set only uses commercial housing of seventy years' lease term excluding the affordable, commercial-residential, state-owned and collectively-owned

²² The market share of Lianjia in Beijing is 50.14% in 2018 according to a report by Beijing Real Estate Agency Association. Retrieved from http://www.yunfangdata.com/news_002/3798.html, 2019.

²³ Conversation with Mr. Shi, oversea business manager of Lianjia, 2016.

properties. All the housing properties involved have a lease year limitation of seventy years, indicating they are built on land with a residential zoning code. Those with a lease year limitation of forty or fifty are built on industrial or commercial land use that have much lower sales prices and thus are excluded from this study. Housing properties that have an area below 6 sqm or located in a basement are removed from our data set. Those with insufficient structural variables are also excluded. The structural information includes the number of bedrooms, living rooms, kitchens, and bathrooms, installation of elevation, heating condition, interior decoration, and building age (see Table 6-1). These variables are selected based on data availability and recommendation of previous studies in China (Jim & Chen, 2006; Kong et al., 2007; Xiao, Li, & Webster, 2016).

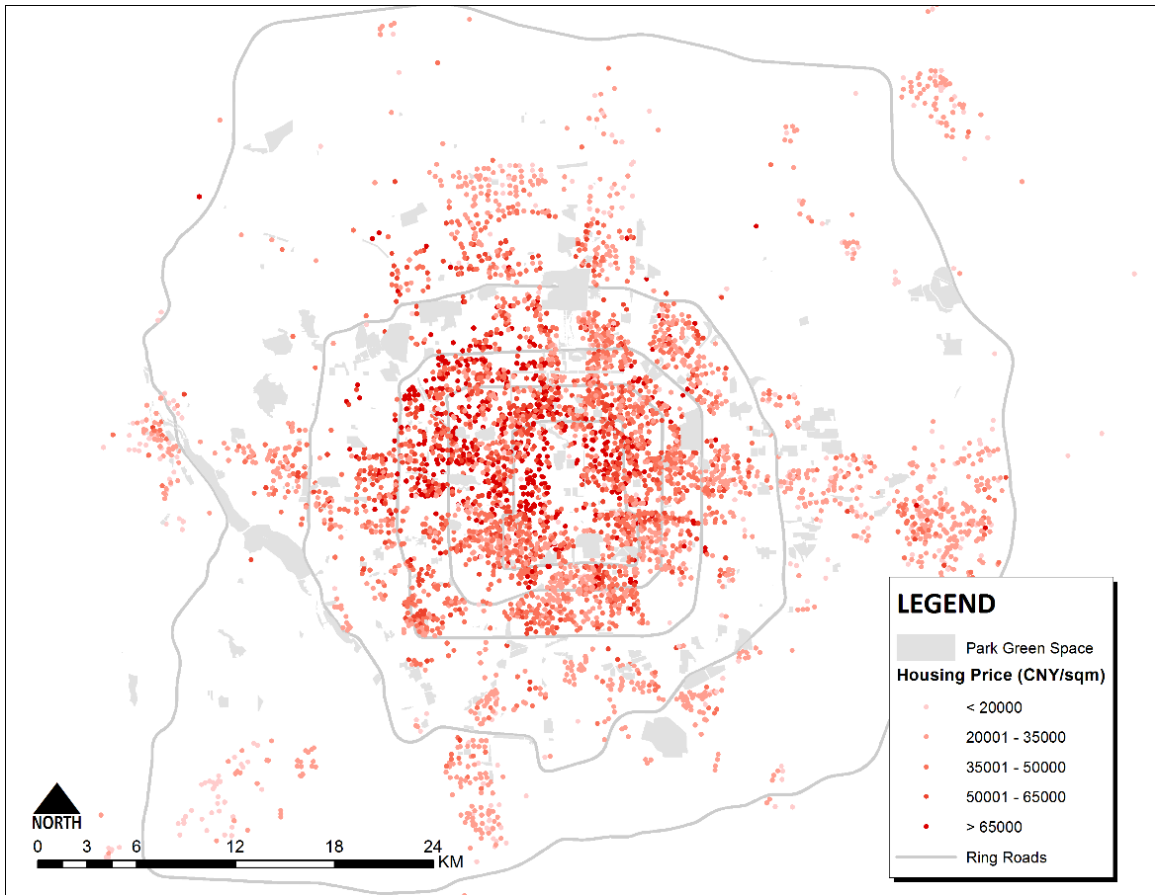


Figure 6-4 Housing price and spatial distribution. Author drawn based on Lianjia, 2018.

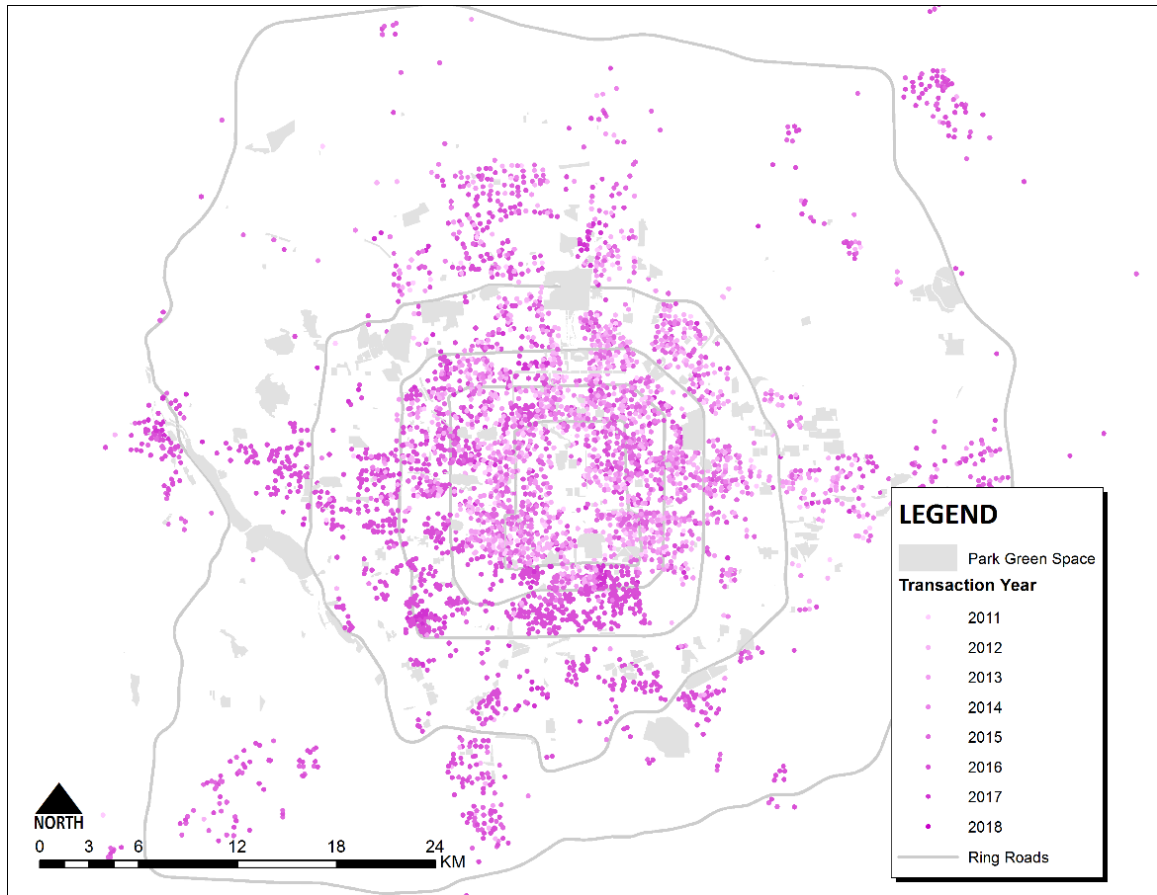


Figure 6-5 Housing transaction year. Author drawn based on Lianjia, 2018.

6.2.6. Neighborhood Amenities and Other Control Variables

Homebuyers are concerned with neighborhood amenities, so the study includes multiple common public amenities such as primary schools, middle schools, universities, hospitals, shopping centers, museums, and subway stations. Geolocations of these amenities are derived from the relevant departments of the Beijing Municipality (Beijing Municipality, 2018). The closest distance from a sold house location to the centroid of each type of amenity is measured as control variables. The georeferencing and accessibility measurement are performed in ArcGIS 10.6.1 (ESRI).

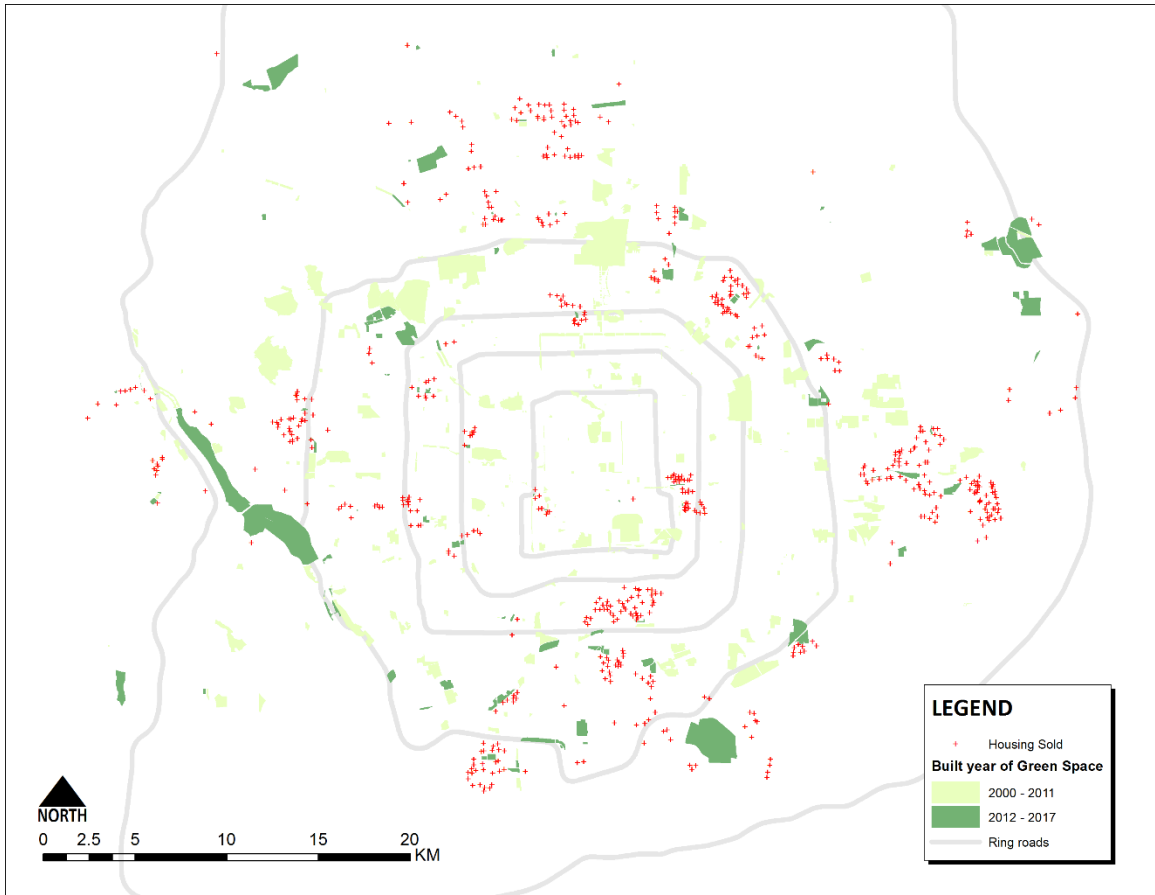


Figure 6-6 Housing transaction used in the study and the newly built green space in 2011-2018. Author drawn based on Lianjia, Google Earth, Gaode Map, and Capital Greening Office, 2018.

Table 6-1 Statistical description of variables.

No. of Observation: 49,502					
Variables	Descriptions	Mean	S.D.	Min	Max
Housing Prices					
t_price	Total housing price (10kCNY)	309.027	202.276	15.000	4,230.000
lnprice	Log of total housing price	5.582	0.531	2.708	8.350
u_price	Housing price per sqm (CNY)	35,546.541	16,445.565	5,100.000	148,051.000
Housing Structural Variables					
b_area	Area of unit(sqm)	87.993	34.069	12.960	640.000
bed	No. of bedroom	2.044	0.757	0.000	7.000
lvng	No. of livingroom	1.256	0.544	0.000	4.000
kit	No. of kitchen	1.001	0.071	0.000	3.000
bath	No. of bathroom	1.223	0.449	0.000	5.000
b_age	Building age (year)	15.771	6.401	2.000	65.000
b_elv	Elavation (dummy: 1=installed)	0.577	0.494	0.000	1.000
b_intr_d	Interior (dummy: 1=with interior decoration)	0.368	0.482	0.000	1.000
b_heat_d	Heating (dummy: 1=collective heating)	0.767	0.423	0.000	1.000
Neighborhood Amenities					
d_tam	Distance to <i>Tian An Men</i> Square (km)	14.789	4.899	2.041	31.211
nd_hosp	Distance to the closest hospital (km)	2.659	1.919	0.096	10.336
nd_shop	Distance to the closest shopping center (km)	0.796	0.661	0.011	5.704
nd_esch	Distance to the closest primary school (km)	0.685	0.416	0.047	2.658
nd_msch	Distance to the closest mid-school (km)	1.046	0.659	0.044	4.038
nd_univ	Distance to the closest university (km)	1.777	1.412	0.025	8.407
nd_msu	Distance to the closest museum (km)	3.641	2.182	0.123	11.606
nd_sub	Distance to the closest subway (km)	1.319	1.141	0.054	8.607
Features of Green Spaces					
g_water	Present of waterbody (dummy: 1=yes)	0.317	0.465	0.000	1.000
g_area_ha	Area of park green space (ha)	36.240	96.487	0.122	499.791
vge_perce	Vegetation coverage ratio (%)	0.898	0.093	0.304	1.000
vge_qualit	Vegetation quality (Avg. NDVI)	0.573	0.053	0.355	0.659
Types of Green Spaces					
g_type_1	Comprehensive Park (dummy)	0.829	0.376	0.000	1.000
g_type_2	Natural Park (dummy)	0.164	0.371	0.000	1.000
g_type_3	Theme Park (dummy)	0.006	0.080	0.000	1.000
g_type_4	Historical Park (dummy)	0.000	0.000	0.000	0.000
post_g	Transaction happened after new greenspace added (dummy: 1=yes)	0.627	0.484	0.000	1.000

Continued on next page

Table 6-1 Continued

Variables	Descriptions	Mean	S.D.	Min	Max
Access to Green Spaces					
g_cd100	Closest greenspace within 100m	0.015	0.120	0.000	1.000
g_cd200	Closest greenspace within 100-200m	0.043	0.204	0.000	1.000
g_cd300	Closest greenspace within 200-300m	0.065	0.246	0.000	1.000
g_cd400	Closest greenspace within 300-400m	0.082	0.275	0.000	1.000
g_cd500	Closest greenspace within 400-500m	0.091	0.287	0.000	1.000
g_cd100_p	Closest greenspace within 100m * post_g	0.011	0.103	0.000	1.000
g_cd200_p	Closest greenspace within 100-200m * post_g	0.027	0.164	0.000	1.000
g_cd300_p	Closest greenspace within 200-300m * post_g	0.043	0.202	0.000	1.000
g_cd400_p	Closest greenspace within 300-400m * post_g	0.057	0.231	0.000	1.000
g_cd500_p	Closest greenspace within 400-500m * post_g	0.058	0.233	0.000	1.000
g_cd100_p_a	Closest greenspace within 100m * post_g * g_area_ha	0.240	2.633	0.000	33.649
g_cd200_p_a	Closest greenspace within 100-200m * post_g * g_area_ha	0.286	2.560	0.000	32.461
g_cd300_p_a	Closest greenspace within 200-300m * post_g * g_area_ha	0.685	4.555	0.000	71.035
g_cd400_p_a	Closest greenspace within 300-400m * post_g * g_area_ha	0.444	4.789	0.000	499.791
g_cd500_p_a	Closest greenspace within 400-500m * post_g * g_area_ha	0.978	4.956	0.000	71.035
g_cd100_p_w	Closest greenspace within 100m * post_g * g_water	0.000	0.000	0.000	0.000
g_cd200_p_w	Closest greenspace within 100-200m * post_g * g_water	0.008	0.091	0.000	1.000
g_cd300_p_w	Closest greenspace within 200-300m * post_g * g_water	0.005	0.070	0.000	1.000
g_cd400_p_w	Closest greenspace within 300-400m * post_g * g_water	0.005	0.071	0.000	1.000
g_cd500_p_w	Closest greenspace within 400-500m * post_g * g_water	0.002	0.049	0.000	1.000
g_cd100_p_vp	Closest greenspace within 100m * post_g * vge_percent	0.010	0.094	0.000	0.985
g_cd200_p_vp	Closest greenspace within 100-200m * post_g * vge_percent	0.024	0.143	0.000	1.000
g_cd300_p_vp	Closest greenspace within 200-300m * post_g * vge_percent	0.038	0.183	0.000	1.000
g_cd400_p_vp	Closest greenspace within 300-400m * post_g * vge_percent	0.050	0.207	0.000	0.978
g_cd500_p_vp	Closest greenspace within 400-500m * post_g * vge_percent	0.053	0.217	0.000	1.000
g_cd100_p_vq	Closest greenspace within 100m * post_g * vge_qualit	0.006	0.060	0.000	0.643

Continued on next page

Table 6-1 Continued

Variables	Descriptions	Mean	S.D.	Min	Max
g_cd200_p_vq	Closest greenspace within 100-200m * post_g * vge_qualit	0.015	0.092	0.000	0.634
g_cd300_p_vq	Closest greenspace within 200-300m * post_g * vge_qualit	0.025	0.118	0.000	0.648
g_cd400_p_vq	Closest greenspace within 300-400m * post_g * vge_qualit	0.032	0.130	0.000	0.634
g_cd500_p_vq	Closest greenspace within 400-500m * post_g * vge_qualit	0.034	0.139	0.000	0.648

6.3. Results

The first model uses all the properties sold (see model 1 in Table 6-2). All estimation results regarding housing structural and neighborhood amenity variables presented expected direction, and are mostly consistent with prior studies in Chinese cities (W. Y. Chen, 2017; Jim & Chen, 2006; Kong et al., 2007; Xiao et al., 2016). The results show that there is strong evidence that houses sold within 100-200m and 300-500m are negatively associated with urban green spaces. But those within 100 and 200-300m are not associated with urban green space (see model 1 in Table 6-2). The association of access to green space with housing price premium is the major focus of this section.

6.3.1. Estimation Results of Features of Green Space

The model 2 (see model 2 in Table 6-2) runs with all housing samples at the city scale. There is strong statistical significance showing that housing sales prices within 100m of newly added green spaces are significantly influenced by the green spaces, and their association being positive. However, adding green spaces within 100-200m from a house pose a negative effect on the transaction price. Housing sales prices are increased by 5.8% when adding a green space located within 100m of the house. This result is similar to many researchers have shown that green space closer to a housing property has a higher premium effect than those further away (Czembrowski & Kronenberg, 2016; Panduro & Veie, 2013; Zheng & Kahn, 2013). Adding new green spaces also has a positive impact (1.6% and 1.7%) on sale prices of housing properties within a distance between 200m and 400m from the green space but the magnitude is lower than those

within 100m from a house sold. Green spaces constructed 400-500m away from a house negatively influence the sale price but the effect is statistically insignificant.

In model 3 (see model 3 in Table 6-2), an interactive term of post-added green spaces and the green space area is created. The area of green space has a positive and statistically significant impact on housing prices if located between 100m and 200m of the houses by 1 ha is associated with an increase of 0.3% in the housing price. However, increasing the area of green spaces within 100m from a house by 1 ha is associated with an increase of 0.1% in the housing price but the effect is marginal. It indicates the larger green spaces that are close to homes are not favorable amenities, and their capacity to trigger gentrification by improving environmental quality is vague. The trend of such positive effect decreases as the green spaces are located farther from the houses.

Model 4 (see model 4 in Table 6-2) tests the influence of green spaces with waterbodies. The results are similar with model 3. If the green space is located within 200m from a house, marginal evidence can be found proving that the presence of a body of water is associated with significant impact on housing price. It indicates that home buyers seem to not appreciate water features in nearby green spaces. If the green space is located within 200m and 300m from a house, the association between the presence of a waterbody feature and the housing transaction price is positive and statistically significant.

The model 5 and model 6 (see model 5 & 6 in Table 6-2) evaluate the quality of vegetation in the added green spaces and their relationships with housing transaction. In model 5, the quality of vegetation is measured by percentage of green space in a given park. The estimation results show that the green space coverage ratio presents a positive

impact on housing transaction for those located within 200m despite statistically insignificant. In model 6, the quality of green space is measured by average value of NDVI. The trend is similar with model 5, in which the house transaction is not strongly associated with the NDVI value if it is located within 200m. In both of the models, the vegetation coverage and quality pose negative impacts on houses sold within 200-300m.

Table 6-2 Impact of green spaces on housing prices

Dep. var	Pre-Existing Pre-Post Comparison					
	Model 1	Model 2 Green space added before housing transaction	Model 3 Interact with area of Green Space	Model 4 Interact with water features of Green Space	Model 5 Interact with vegetation coverage	Model 6 Interact with vegetation quality
Housing Structural Variables						
b_area	0.007***	0.007***	0.007***	0.007***	0.007***	0.007***
bed	0.079***	0.078***	0.079***	0.078***	0.078***	0.078***
lvng	0.072***	0.072***	0.072***	0.072***	0.071***	0.071***
kit	0.119***	0.119***	0.118***	0.118***	0.119***	0.119***
bath	-0.042***	-0.042***	-0.042***	-0.042***	-0.041***	-0.041***
b_age	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***
b_intr_d	0.044***	0.044***	0.043***	0.043***	0.043***	0.043***
b_heat_d	0.028***	0.028***	0.028***	0.028***	0.028***	0.028***
b_elv	0.046***	0.046***	0.046***	0.046***	0.046***	0.046***
Neighborhood Amenities Variables						
d_tam	-0.045***	-0.045***	-0.046***	-0.045***	-0.044***	-0.045***
nd_hosp	0.028***	0.027***	0.028***	0.027***	0.027***	0.027***
nd_msch	-0.016***	-0.015***	-0.018***	-0.016***	-0.016***	-0.017***
nd_esch	0.056***	0.056***	0.058***	0.057***	0.058***	0.058***
nd_msu	-0.009***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***
nd_shop	-0.021***	-0.022***	-0.023***	-0.022***	-0.022***	-0.022***
nd_univ	0.044***	0.044***	0.045***	0.043***	0.043***	0.044***
nd_sub	-0.021***	-0.020***	-0.020***	-0.020***	-0.019***	-0.020***
Distance and Feature of Green Spaces Related Variables						
g_cd100	0.013	-0.025	-0.022	-0.025	-0.018	-0.019
g_cd100_p		0.058***	0.045*	0.058***	-0.142	0.246
g_cd100_p_a			0.001			
g_cd100_p_w				N/A		
g_cd100_p_vp					0.219	
g_cd100_p_vq						-0.333
g_cd200	-0.027***	-0.013*	-0.013*	-0.013*	-0.012	-0.011
g_cd200_p		-0.022**	-0.054***	-0.027***	-0.071	-0.040
g_cd200_p_a			0.003***			
g_cd200_p_w				0.012		
g_cd200_p_vp					0.055	
g_cd200_p_vq						0.032
g_cd300	-0.003	-0.013*	-0.014**	-0.013**	-0.012*	-0.012*
g_cd300_p		0.016*	0.041***	0.012	0.360***	0.478***
g_cd300_p_a			-0.002***			
g_cd300_p_w				0.032**		
g_cd300_p_vp					-0.381***	
g_cd300_p_vq						-0.791***
g_cd400	-0.028***	-0.040***	-0.041***	-0.040***	-0.039***	-0.040***
g_cd400_p		0.017**	0.014*	0.017**	-0.066	0.056
g_cd400_p_a			0.000			
g_cd400_p_w				-0.003		
g_cd400_p_vp					0.093*	
g_cd400_p_vq						-0.072

Continued on next page

Table 6-2 Continued

Dep. var	Model 1	Model 2 Green space added before housing transaction	Model 3 Interact with area of Green Space	Model 4 Interact with water features of Green Space	Model 5 Interact with vegetation coverage	Model 6 Interact with vegetation quality
g_cd500	-0.017***	-0.014**	-0.014**	-0.014**	-0.014**	-0.013**
g_cd500_p		-0.004	0.020**	-0.002	-0.210***	0.014
g_cd500_p_a			-0.001***			
g_cd500_p_w				-0.033*		
g_cd500_p_vp					0.223***	
g_cd500_p_vq						-0.033
Constant	4.497***	4.497***	4.504***	4.498***	4.489***	4.496***
Observations	49,502	49,502	49,502	49,502	49,502	49,502
R-squared	0.869	0.870	0.870	0.870	0.870	0.870
Dist FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6.3.2. Estimation Results of Different Types of Green Space

The study also runs different types of green spaces separately to test their effects on gentrification (see Table 6-3). The historical parks and theme parks are excluded since there are few houses sold within a 3000m distance. The two types of green spaces treated show divergent patterns of impact on housing sales prices.

For Comprehensive Parks, the premium effect of newly added ones within 100m of sold houses is positive and statistically significant. Adding one park within close distance of 100m can increase the housing price by 8.3%. Within 100-500m, comprehensive parks have mostly negative effects on housing prices, except for the 300-400m band.

The premium effect of Natural Parks is marginal for those located within 100m from a sold house, though the influence is positive. Those located within 100m and 200m

bring a negative impact on housing price, the it is statistically insignificant. Home buyers tend not to appreciate natural parks when buying a house, if it is located within 200m from a natural park. Interestingly, housing price received positive and strong premium effects from natural parks within 200-500m from the location of a sold house, among which the highest premium effect is 7.1% (400-500m band) for the total price.

Table 6-3 Impact of different types of green spaces on housing prices

Dep. var	(1) Comprehensive Park	(2) Natural Park
Housing Structural Variables		
b_area	0.007***	0.008***
bed	0.082***	0.046***
lvng	0.077***	0.053***
kit	0.076***	0.328***
bath	-0.032***	-0.067***
b_age	-0.010***	-0.014***
b_intr_d	0.037***	0.058***
b_heat_d	0.009***	0.128***
b_elv	0.028***	0.033***
Neighborhood Amenities Variables		
d_tam	-0.043***	-0.012
nd_hosp	0.032***	-0.026**
nd_msch	0.017***	-0.025***
nd_esch	-0.007	0.087***
nd_msu	-0.001	0.007
nd_shop	-0.001	0.028*
nd_univ	0.031***	0.034***
nd_sub	-0.021***	-0.006
Distances to Green Spaces		
g_cd100	-0.083***	0.070**
g_cd100_p	0.081***	0.033
g_cd200	-0.026***	0.144***
g_cd200_p	-0.019**	-0.027
g_cd300	0.012	-0.080***
g_cd300_p	-0.002	0.042***
g_cd400	-0.052***	n/a
g_cd400_p	0.019***	n/a
g_cd500	-0.005	-0.137***
g_cd500_p	-0.011*	0.071***
Constant	4.514***	4.119***
Observations	41,045	8,142
R-squared	0.868	0.895
Dist FE	YES	YES
Year FE	YES	YES

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

6.3.3. Graphical Analysis and Falsification Test

The difference-in-difference estimation is valid based on an assumption that the green space is not added within 3km from houses, where the housing market presents a growing trend. If the housing market within 500m from a new green space is growing much faster than other areas, the estimation results might be spurious in the DID model. The preexisting trend can be examined by graphic illustration of housing price in different distances from a new green space (Pope & Pope, 2015). Based on a previous study (Pope & Pope, 2015), the first step of conducting this graphical test is to run a regression using model 1 in Table 6-2 without including spatial indicators and interaction terms. Second, the residual is aggregated by quarter of year to show only two years before and after adding a new green space, for each spatial interval. The graph in Appendix 8.6 shows that the residuals of houses in all spatial zones are changing similarly. Before adding new green space, the housing market fluctuates and shows a downward trend, and after the construction of green space, the market experiences a steep growth. Therefore, the graphical test supports the assumption of the DID model.

Falsification test is another effective approach for examining whether increasing housing market trends in different spatial locations influence premium effect of newly added green spaces. A false construction date of green space is created in the model 2 of Table 6-2 by bringing forward the dates of one, two, and three years. The results presented in Appendix 8.7 provide little evidence supporting the spurious, positive effect of green spaces (within 100-500m from a house) on housing sales price. The positive effect of those houses located within 100m of green spaces might relate to the announcement of an urban plan that is often posted publicly after approval. Another explanation is about the construction time of a park. Particularly for large forest parks,

construction lasts months, even a year. The initial constructed part of a park can signal to home buyers that there would be large park in the future, which may add to housing premium effect. In sum, the two tests support the assumption of the DID model and causal interpretation of estimation.

6.4. Discussions

6.4.1. Does Adding New Green Spaces Spur Gentrification?

As expected, adding new green spaces can trigger gentrification by increasing the housing prices in the neighboring communities in general. However, the capitalization scale of green spaces depends based on a variety of features. Distance to a property, area, vegetation quality, presence of water features, and types of green space all play different roles in affecting the housing price thus having divergent capacity of triggering gentrification.

6.4.2. How Are Different Features of Green Space Associated with Gentrification, and How Strongly?

In general, green space located within 100m exerts a high positive impact on housing prices, which is similar with previous research (Crompton, 2005). Those located within 100-200m pose negative impact on housing prices. One possible explanation for this relates to the site selection process of green space planning in Beijing. As environmental improvement function is a primary concern of Beijing, green spaces are proposed to mitigate environmental degradation, hence the addition of new green spaces are often located close to sources of pollution. In many cases, green spaces are found surrounded by wide arterial roads or industrial land uses serving mainly as buffers. Even worse, the park installation is also followed by aggregation of many industrial projects—adding more disamenities. These parks, though providing multiple benefits, end up encompassed by farmlands, industrial warehouses, or factories amongst urban areas in Beijing, which neutralize the premium effect potentially brought about by these new green spaces.

Another possibility is subject to the funding mechanism of urban green spaces provision. As noted in section 0, the major financial source for Chinese municipalities for funding public infrastructures, including green space, come from land leasing revenue (W. Y. Chen & Hu, 2015). Considering high land reclamation cost for installing new public green spaces and their limited profit-generation capacity, funding for green space construction is often constrained. To fully achieve the requirement of upper level plans and decisions of policy makers within the given limited funding, the planners often have to lower land reclamation and installation costs as much as possible. Undesirable and inexpensive land such as brownfields, abandoned mine pits, and agricultural lands are widely preferred (Beijing Local Chronicles Compilation Committee, 2000). However, these areas within the complete built park boundaries are not fully cleaned, and thus considered disamenities that are less favorable among home buyers. For example, many large-scale afforestation projects that are recently being carried out in the middle of farmlands utilize existing natural forest and buffer trees on the farmland (another way to reduce cost of green space construction). The existing buffer trees, though included in the park, are low quality vegetation with little usability. As a result, if a house sold is close to these passive amenities within a green space, the green space poses a negative influence on the sold prices.

Except those located within 200-300m from sold houses, the area of green spaces positively influences the housing prices within 200m. Larger area of green spaces are more favorable features for home buyers. This also reflected the possibility of negative amenities in the vicinity of a green space diminishing the premium effect. Because the larger a park the higher possibility it includes more negative amenities.

Water features in green spaces can also be seen as undesirable when the green space is within 200m from a sold house. The poor quality of waterbodies in parks could be attributable to such disamenity, or the negative features surrounding green spaces contribute to the decreasing of housing cost.

The features of vegetation—measured by green space coverage ratio and NDVI value—have a similar trend on influencing housing transaction prices in the vicinity. The premium effect is marginal as distance close to a house increases, indicating parks with larger portions of vegetation or higher vegetation quality are less attractive for home buyers. This might also relate with the negative amenity comes along with parks. The well-greened parks with high vegetation coverage often are those forest or countryside parks located in the periphery of Beijing, which often surrounded by abovementioned less appreciated land uses.

6.4.3. How Are Different Types of Green Space Associated with Gentrification, and How Strongly?

Consistent with previous studies (Czembrowski & Kronenberg, 2016; Panduro & Veie, 2013), different green spaces are not homogeneous amenities and can present differing influences on housing prices, thus causing varying degrees of gentrification. Comprehensive Parks and Natural Parks can both pose the high effect on housing price. But the effectiveness of spurring gentrification of the two types are related with their distances to housing properties.

Comprehensive Parks have the highest appreciation effect (8.1%) on houses located within 100m, while they pose a negative impact on the houses located between 100-200m and 400-500m (-1.9% and -1.1% respectively). The positive premium effect

on neighboring properties are consistent with previous studies (Crompton, 2005; Jim & Chen, 2006; Kong et al., 2007; Zheng & Kahn, 2013). Comprehensive Parks usually have more diverse facilities, well-designed spaces, and sufficient maintenance than other types, contributing to the raise of housing price. The negative impact might be related with the certain undesirable amenities around newly added comprehensive parks as mentioned above in 6.4.2.

Natural Parks have the highest impact on housing prices (premium effect at 7.1%) within a distance of 400-500m from a property, thus, generating gentrification at the highest magnitude. However, home buyers do not appreciate the Natural Parks in close vicinity (within 200m), which pose statistically non-significant impact for houses located within 100m and a negative impact for those in the 100-200m distance. Natural Parks within the distance of 200-400m away from a property also have positive premium effects. This confirms the abovementioned explanation about the coexistence of negative amenities around most natural parks—newly added parks are in the middle of pollution-sources such as farmlands or factory land uses.

The high impact of Natural Parks on housing sales prices from further distances could also be explained by the implementation or role of these parks in urban planning. In some cases, they are part of large urban revitalization projects which bring multiple other urban amenities into the vicinity. However, the location of new parks is often far from the core area of a plan, where more desirable amenities are located which have a greater capacity to increase the premium on housing prices during the development process.

6.4.4. Potential Implication in Urban Green Space Planning

The estimation results reveal how residents value the construction of green spaces in the vicinity of their communities, and thus influence housing sales price—an effective indicator for gentrification. The empirical results can be used to predict the dislocation effect due to potential gentrification outcomes from urban green space planning and greening policies to be implemented in Beijing. Dislocation effects due to green space-associated gentrification could harm spatial equality of urban green space planning, which is one of the important goals of the municipality. The hedonic pricing approach can inform the planning process in determining the types and different features of green spaces by providing insight into housing price premium effects of different kinds of green spaces. It could also be a reference for making inclusive policies or planning schemes when installing green spaces with particular features that are known to raise peripheral housing prices to an unaffordable level.

6.5. Summary of Section 6

This section investigates whether adding green spaces results in the gentrification of neighboring areas, thereby dislocating lower social groups who can no longer afford living in such areas due to the cost increase stemming from improved environmental quality. If such a trend is observed, the marginalized groups are excluded from benefiting from afforestation projects which are ostensibly equally accessible. The estimation results show that adding new green spaces can trigger gentrification by increasing the housing prices in the neighboring communities in general. However, the capitalization scale of green spaces depends based on a variety of features. Distance to a property, area, vegetation quality, presence of water features, and types of green space all play different roles in affecting the housing price and thus have divergent capacities of triggering gentrification.

7. Conclusion

7.1. Summary of Findings

The global regressions indicate that public green spaces tend to better serve the marginalized groups. Advantaged socio-economic groups are well served by internal vegetations in the gated communities in which they live. The Geographically Weighted Regression output mappings indicate that there are inconsistent relationships between access to green spaces and the socio-economic status of residents. The socio-spatial patterns of accessing green spaces in Beijing is a result of the interplay of many factors, from the city's original geographical characteristics, to the historical layout of the old city, urban planning and land use decisions, afforestation policies and projects, and even the public financial stresses involved in urban greening efforts.

Although green spaces increased significantly during the period, the global regression estimation did not identify significant associations between the changes of green spaces and the socio-economic statuses in Township (census tract unit). Little evidence can be found that park implementation favors or discriminates any marginalized groups. In terms of vegetation changes, the only statistically significant results relate to the socio-economic changes measured by local *Hu Kou* population and education level. For these studies, the estimation coefficients are both positive, showing that increases in vegetation are associated with the increase of census tract with higher proportion of local *Hu Kou* and higher employment, i.e. more advantaged social groups. The Geographically Weighted Regression identified inconsistent relationships between the changes of green space accessibility and socio-economic statuses. Potential factors causing the variances of

local relationships between the changes of green space accessibilities and socio-economic statuses are illustrated and discussed.

The estimation results show that adding new green spaces might trigger gentrification by increasing the housing prices in the neighboring communities in general. However, the capitalization scale of green spaces depends based on a variety of features. Distance to a property, area, vegetation quality, presence of water features, and types of green space all play different roles in affecting the housing price and thus have divergent capacities of triggering gentrification.

7.2. Application in Urban Green Space Planning and Design

7.2.1. Identify the socio-spatial discrepancies of accessing green space at a city scale

To address the inequality, we must first understand the socio-spatial patterns of accessing green spaces. The results of spatial discrepancies of accessing green spaces identify the specific locations, where green spaces are relatively lacking regarding the area and quality in Beijing. By using residential communities, this dissertation reveals local demands of green spaces of different social groups at a finer scale.

7.2.2. Assist to promote location specific policy and regulation for inclusive urbanization

Another application of this research to mitigate the undesirable outcomes of the afforestation projects and to promote more inclusive urban development. The gentrification effects of different types of green spaces can inform decision makers to adopt location sensitive policies and compensation approaches, particularly when implementing large scale urban afforestation projects, which are known to gentrify the neighboring communities by augmenting the housing costs.

7.2.3. Provide evaluating approach for enhancing comprehensive green space implementation

Apart from direct informative implementation of the empirical results from this dissertation, the evaluation methods integrating varying features of green spaces and the socio-economic backgrounds of potential users can add more sophisticated tools in contemporary planning guidance and evaluation approaches in China. In fact, there is no technical approach in urban planning practice to identify the socio-spatial pattern in China. Instead, professionals rely on over-simplified indicators such as green space area

per capita or green space coverage ratio to guide the planning and evaluation of green space provision, which often leads to undesirable spatial patterns of green spaces, in turn hindering the ability to serve a broader population.

7.3. Limitations and Future Studies

7.3.1. Seasonality of green spaces

Seasonality of green spaces influence the degrees of ecosystem services provided to urban residents. The appearances of plants vary as season changes. Particularly in northern China, the landscape in urban green space present huge differences between summer and winter, hence affecting the benefits such as aesthetic value, recreational services, air purification capacities to certain extent. Seasonality of visitors affect the benefits of green spaces, particularly those famous historical gardens such as the *Summer Palace*, *Tian Tan*, and *Yuan Ming Yuan*. During the national holidays, these gardens have a large volume of visitors limiting its capacity to serve neighboring communities on a daily basis. The high congestion level provides few spaces for the locals. Integrating such nuances might generate different results and produce more time-sensitive maps of accessibility patterns.

7.3.2. People's preference and perceptions

When measuring the accessibility of urban green spaces, this dissertation only considers the physical dimensions of potential visitors without including their psychological aspects. Studies have indicated that people of different ages have different senses and/or perceptions of accessibility (Byrne & Wolch, 2009). Additionally, the socio-economic statuses of people might influence their perceptions even their capabilities of accessing urban green spaces. It is entirely possible that a wealthy resident living in the dense traditional courtyard—the *Hu Tong*—within the old city (bordered by the 2nd Ring Road) might not care about the daily access to a near green spaces. In fact, the person is able to drive far to a natural reserve in the north of Beijing during a long

weekend or holiday. Those living in the southern or eastern outskirts (between the 4th and 5th Ring Roads) might be concerned with other aspects of daily lives such as education, medical services, and employment opportunities over the green spaces. A further study involving sampled survey or interviews might distinguish such differences.

8. Appendix

8.1. Diagnostic of OLS for Spatial Autocorrelation in 4.3.1

Table 8-1 Diagnostics for spatial dependence (park access and socioeconomic status)

Diagnostics for spatial dependence			
TEST	MI/DF	VALUE	PROB
Moran's I (error)	0.8004	69.8888	0.00000
Lagrange Multiplier (lag)	1	4890.0649	0.00000
Robust LM (lag)	1	29.1690	0.00000
Lagrange Multiplier (error)	1	4861.7708	0.00000
Robust LM (error)	1	0.8749	0.34959
Lagrange Multiplier (SARMA)	2	4890.9398	0.00000

Table 8-2 Diagnostics for spatial dependence (vegetation coverage percentage and socioeconomic status)

Diagnostics for spatial dependence			
TEST	MI/DF	VALUE	PROB
Moran's I (error)	0.8108	70.7789	0.00000
Lagrange Multiplier (lag)	1	4965.7214	0.00000
Robust LM (lag)	1	13.0949	0.00030
Lagrange Multiplier (error)	1	4989.7651	0.00000
Robust LM (error)	1	37.1386	0.00000
Lagrange Multiplier (SARMA)	2	5002.8600	0.00000

8.2. Report of Geographically Weighted Regression in 4.3.2

Table 8-3 Report of GWR between access to parks and socioeconomic status

VARNAME	VARIABLE
Neighbors	23
ResidualSquares	4587.884879
EffectiveNumber	659.7102661
Sigma	1.520943825
AICc	10235.53457
R2	0.878201882
R2Adjusted	0.837749058
Dependent Field	Socio-economic rank
Explanatory Field	Access to parks

Table 8-4 Report of GWR between vegetation coverage percentage and socioeconomic status

VARNAME	VARIABLE
Neighbors	25
ResidualSquares	4375.855058
EffectiveNumber	710.0632039
Sigma	1.504605474
AICc	10208.63633
R2	0.883830801
R2Adjusted	0.841216213
Dependent Field	Socio-economic rank
Explanatory Field	Percentage of vegetation

8.3. Adjustment of Administrative Divisions in Beijing

The areas of several administrative division were changed between the 2000 and 2010 Censuses, respectively. To compare the changes of socio-economic status as well as the provision of urban green spaces, equivalent administrative borders metrics are needed. Some administrative divisions had only minor alteration of their borders—such as moving from one side of a road to the midline—and therefore remain the same. However, major border alterations happened in some divisions where a large area—including a few residential communities—were assigned to neighboring divisions. My adjustments only consider this latter case. The neighboring divisions that retained the same border are merged and considered as one administrative unit for the analysis in this dissertation. Below is a description of my border unification alterations.

1. *Hai Dian* District

- *Shang Di Jiedao*, *Xi Bei Wang Zhen*, and *Ma Lian Wa Jiedao* are merged to one administrative unit.
- *Si Ji Qing Zhen* and *Shu Guang Jiedao* are merged to one administrative unit.

2. *Shi Jing Shan* District

- *Lao Shan*, *Ba Jiao*, *Lu Gu*, and *Ba Bao Shan Jiedao* are merged to one administrative unit.

3. *Feng Tai* District

- *Da Hong Men Jiedao*, and *He Yi Jiedao* are merged to one administrative unit.

4. *Chao Yang* District

- *Lai Guang Ying Xiang*, and *Dong Hu Jiedao* are merged to one administrative unit
- *Ya Yun Cun*, *Da Tun*, and *Ao Yun Cun Jiedao* are merged to one administrative unit.

5. *Xicheng* District

- *Xin Jie Kou*, *Chang Qiao*, and *Fu Sui Jing Jiedao* are merged to one administrative unit.

8.4. Land Use Classification Accuracy Assessment

The classification of land use is conducted on ArcGIS 10.6.1 platform (ESRI).

The reclassification accuracy assessment used 258 randomly generated²⁴ points for ground comparison based on historical high-resolution satellite images from Google Earth. classification is 90.18% and 88.51% respectively for the year 2000 and 2010.

Table 8-5 Land Use Classification Accuracy Assessment for the year 2000

Land Use	Land Use Prediction	Ground Truth1	Ground Truth2	Ground Truth3	Ground Truth4	Ground Truth5	Percentage	Predictions
Urban	1	101	6	3	2	0	90.18%	112
Farm	2	2	36	0	0	0	94.74%	38
Park	3	5	16	38	3	12	51.35%	74
Water body	4	0	0	0	10	0	100.00%	10
Forest	5	0	1	0	0	23	95.83%	24
Percent		93.52%	61.02%	92.68%	66.67%	65.71%	80.62%	
Ground Truths		108	59	41	15	35	258	

Table 8-6 Land Use Classification Accuracy Assessment for the year 2010

Land Use	Land Use Prediction	Ground Truth1	Ground Truth2	Ground Truth3	Ground Truth4	Ground Truth5	Percentage	Predictions
Urban	1	131	11	5	0	1	88.51%	148
Farm	2	4	20	1	0	0	80.00%	25
Park	3	1	9	40	0	1	78.43%	51
Water body	4	0	0	0	10	0	100.00%	10
Forest	5	0	0	0	0	24	100.00%	24
Percent		96.32%	50.00%	86.96%	100.00%	92.31%	87.21%	
Ground Truths		136	40	46	10	26	258	

²⁴ A “Stratified Random” sampling strategy is adopted.

8.5. Diagnostic of for Spatial Autocorrelation in 5.3.2

Table 8-7 Diagnostics for spatial dependence (park access and socioeconomic status)

Diagnostics for spatial dependence			
TEST	MI/DF	VALUE	PROB
Moran's I (error)	0.0991	2.1392	0.03242
Lagrange Multiplier (lag)	1	4.0583	0.04396
Robust LM (lag)	1	1.2963	0.25489
Lagrange Multiplier (error)	1	3.1458	0.07612
Robust LM (error)	1	0.3839	0.53554
Lagrange Multiplier (SARMA)	2	4.4421	0.10849

Table 8-8 Diagnostics for spatial dependence (vegetation coverage percentage and socioeconomic status)

Diagnostics for spatial dependence			
TEST	MI/DF	VALUE	PROB
Moran's I (error)	0.3148	6.1692	0.00000
Lagrange Multiplier (lag)	1	41.3593	0.00000
Robust LM (lag)	1	9.7287	0.00181
Lagrange Multiplier (error)	1	31.7717	0.00000
Robust LM (error)	1	0.1411	0.70717
Lagrange Multiplier (SARMA)	2	41.5004	0.00000

8.6. Graphical Analysis for Regression Results in 6.3.1

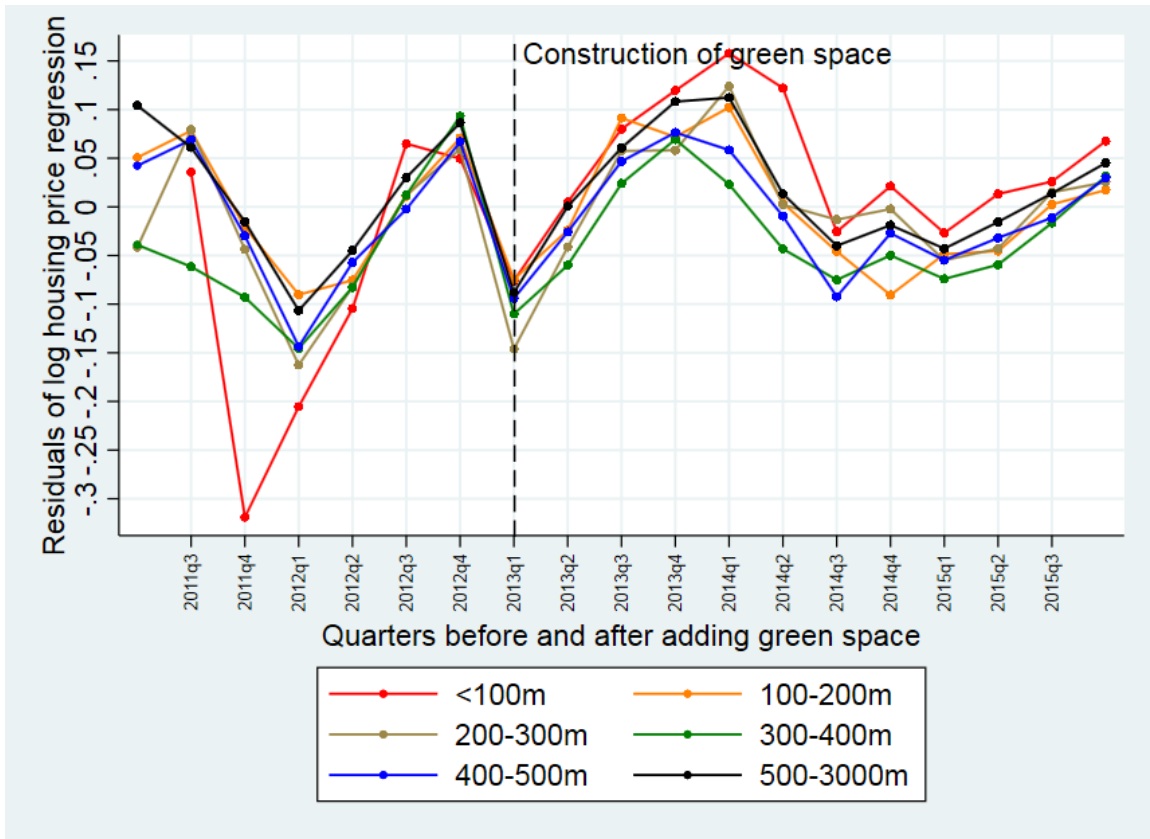


Figure 8-1 Residual plot of log price regression before and after green space built time

8.7. Falsification Test for Regression Results in 6.3.1

Table 8-9 Falsification test for impact of adding green spaces on housing price

Dep. var	Names	Falsification test 1-year earlier	Falsification test 2-year earlier	Falsification test 3-year earlier
Structural Variables				
b_area	Area of unit(sqm)	0.007***	0.007***	0.007***
bed	No. of bedroom	0.079***	0.079***	0.079***
lvng	No. of livingroom	0.072***	0.072***	0.072***
kit	No. of kitchen	0.119***	0.119***	0.119***
bath	No. of bathroom	-0.042***	-0.042***	-0.042***
b_age	Building age (year)	-0.009***	-0.009***	-0.009***
b_intr_d	Interior (1=decoration)	0.044***	0.044***	0.044***
b_heat_d	Heating (1=collective heating)	0.029***	0.028***	0.028***
b_elv	Elavation (1=yes)	0.046***	0.046***	0.046***
Neighborhood Amenities				
d_tam	Distance to TianAnMen Square (m)	-0.045***	-0.045***	-0.045***
nd_hosp	Distance to the closest hospital (m)	0.027***	0.028***	0.028***
nd_msch	Distance to the closest mid- school (m)	-0.016***	-0.016***	-0.017***
nd_esch	Distance to the closest primary school (m)	0.056***	0.057***	0.057***
nd_msu	Distance to the closest museum (m)	-0.008***	-0.009***	-0.009***
nd_shop	Distance to the closest shopping center (m)	-0.022***	-0.021***	-0.020***
nd_univ	Distance to the closest university (m)	0.044***	0.044***	0.044***
nd_sub	Distance to the closest subway (m)	-0.021***	-0.021***	-0.021***
Green Space added				
g_cd100	Closest greenspace within 100m	-0.067***	-0.135***	-0.231***
g_cd100_f0p	Within 100m * 1yr before transaction	0.096***		
g_cd100_f1p	Within 100m * 2yr before transaction		0.158***	
g_cd100_f2p	Within 100m * 3yr before transaction			0.259***

Continued on next page

Table 8-9 Continued

g_cd200	Closest greenspace within 100-200m	-0.017*	-0.020	-0.032**
g_cd200_f0p	Within 100-200m * 1yr before transaction	-0.012		
g_cd200_f1p	Within 100-200m * 2yr before transaction		-0.008	
g_cd200_f2p	Within 100-200m * 3yr before transaction			0.005
g_cd300	Closest greenspace within 200-300m	-0.012	-0.014	-0.018
g_cd300_f0p	Within 200-300m * 1yr before transaction	0.011		
g_cd300_f1p	Within 200-300m * 2yr before transaction		0.013	
g_cd300_f2p	Within 200-300m * 3yr before transaction			0.016
g_cd400	Closest greenspace within 300-400m	-0.055***	-0.029***	-0.048***
g_cd400_f0p	Within 300-400m * 1yr before transaction	0.033***		
g_cd400_f1p	Within 300-400m * 2yr before transaction		0.002	
g_cd400_f2p	Within 300-400m * 3yr before transaction			0.022
g_cd500	Closest greenspace within 400-500m	-0.013*	-0.025***	-0.047***
g_cd500_f0p	Within 400-500m * 1yr before transaction	-0.005		
g_cd500_f1p	Within 400-500m * 2yr before transaction		0.010	
g_cd500_f2p	Within 400-500m * 3yr before transaction			0.033**
Constant	Constant	4.500***	4.498***	4.500***
Observations		49,502	49,502	49,502
R-squared		0.870	0.870	0.870
Dist FE		YES	YES	YES
Year FE		YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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