THE ELDERLY IN GREEN SPACES: UNDERSTANDING, MAPPING, AND PLANNING FOR NATURE-BASED RECREATION

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THE ELDERLY IN GREEN SPACES: UNDERSTANDING, MAPPING, AND PLANNING FOR NATURE-BASED RECREATION

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DECLARATION OF AUTHORSHIP

I declare that I have completed the doctoral thesis independently and have not used any sources or means other than those indicated. The work has not previously been submitted as a thesis or an examination paper.

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Chen Wen

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LIST OF ABBREVIATIONS

ESTIMAP	Ecosystem Services Mapping Tool
GIS	Geographical Information System
NBR	Nature-based recreation
PPGIS	Public Participatory Geographical Information System
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
2SFCA	The two-step floating catchment area

ABSTRACT

The demographic structure of many cities in Europe and around the world is characterized by an increasing proportion of elderly people. This poses challenges for landscape planning: it must play greater attention to elderly people and provide opportunities to improve their quality of life through green spaces. Nature-based recreation (NBR) plays an essential role in elderly people's quality of life. It can improve their physical fitness, mental health, and social contact. Therefore, landscape planning should be expected to respond to population aging by developing urban green spaces so that they can provide these multiple benefits to the elderly.

However, elderly people's needs and preferences have attracted little attention in the planning of urban green spaces. First, with regard to elderly people's specific preferences for green spaces, existing knowledge is scattered and lacks an interpretation for planning purposes. Few studies have sought to achieve a systematic understanding either of elderly people's NBR preferences in different types of green spaces, or of the differences between the preferences of elderly groups and young groups. Secondly, it was unclear whether and how NBR opportunities of a city could be spatially assessed in order to create a basis for planning that better takes into account elderly people. Third, despite growing academic attention being paid to issues of environmental justice, the age perspective has not been closely examined, especially in terms of accessibility to urban green spaces.

To fill the identified knowledge gaps, this thesis aims to provide a systematic understanding of elderly people's preferences for NBR, to spatially assess NBR opportunities and demands, and to investigate the equality in access to NBR for elderly people. The thesis is organized by the following research questions. The first question concerns the state of scientific knowledge and asks: (1) What landscape characteristics and green space features are preferred by elderly people? The second and third questions refer to an empirical investigation in the case study of Hannover, Germany. The questions are: (2) What recreation potentials, opportunities, and demands of elderly people for NBR exist in the Hannover urban area? (3) How equitable is the access of the elderly to green spaces at the census block level in Hannover?

For the first objective of synthesizing evidence of preferences, a systematic literature review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. This review analyzed 44 peer-reviewed articles in depth that were published between 2000 and 2017. The results were summarized in a framework of factors regarding elderly people's preferences. The framework consists of four categories: landscape features (e.g. aesthetics, legibility, and cultural heritage), infrastructure and facilities (e.g. trails, recreational facilities, and business settings), maintenance (e.g. cleanliness and security), and accessibility.

For the second objective of mapping NBR opportunities, a spatial model was built to understand elderly people at the city scale, based on the ESTIMAP recreation model. The adapted model considers special factors and parameters to better reflect elderly people's preferences for NBR at the city scale. It assesses NBR opportunities by considering landscape aesthetics, various types of facilities, and proximity. The results of a case study in Hannover revealed that only parts of urban green spaces offer high recreation opportunities for the elderly, even though the city has many urban parks. Places with high opportunities are mainly found near the lake in the southern city and in the urban forests near the northeast, while the high demand is mainly found in a strip of residential areas across the city center.

For the third objective of assessing equality of access to urban green spaces, an enhanced "two-step floating catchment area" (2SFCA) approach was developed to measure per capita green area. This enhanced approach considers the attractiveness of green spaces, the actual street network, and crowding issues. It tested two scenarios that represent two mobility levels with respect to elderly people and the general population. The results showed that in the scenario of "moderate mobility" (for elderly people), the per capita value in each census block is less than that in the scenario of "better mobility" (the general population). The "moderate mobility" scenario displayed a more uneven distribution of access across the districts of Hannover. The bivariate correlation analysis showed no evidence that census blocks with a higher percentage of the elderly population suffer from worse access to urban green spaces.

This research provided a systematic understanding of elderly people's preferences for NBR and approaches to assessing them spatially. Based on the findings, following planning recommendations were proposed to consider elderly people's preferences in

developing urban green spaces: (1) A spatial assessment of elderly people's preferences can help to create a basis for green space planning. (2) The distribution of urban green spaces should be optimized to fulfill elderly people's demands and to alleviate inequality in access to areas with high recreation opportunities. (3) Facilities and infrastructure are vital to urban green space development. Many green spaces are aesthetically pleasing, and their NBR potential can be better pursued by improving facilities and infrastructure. Future studies are suggested to examine more closely how cultural contexts would affect elderly people’s preferences for NBR and to consider temporal and spatial dynamics of demographic changes in planning green spaces.

Keywords: Elderly people, nature-based recreation, landscape planning, public health

ZUSAMMENFASSUNG

Die demographische Entwicklung vieler Städte in Europa und der ganzen Welt ist durch einen zunehmenden Anteil älterer Menschen charakterisiert. Dies stellt die Landschaftsplanung vor Herausforderungen: Sie muss die ältere Bevölkerung stärker in den Blick nehmen, um auch für sie die Möglichkeiten zur Gesundheitsvorsorge und Lebensqualität durch Grünflächen und einen gleichberechtigten Zugang zu diesen zu ermöglichen. Naturnahe Erholung (NE) spielt eine wesentliche Rolle für die Lebensqualität älterer Menschen: Sie kann ihre körperliche Fitness, ihre geistige Gesundheit und ihre sozialen Kontakte verbessern. Die Landschaftsplanung sollte auf die Alterung der Bevölkerung reagieren, indem sie städtische Grünflächen entwickelt, die an die Bedürfnisse der Senioren angepasst sind.

Den Bedürfnissen und Präferenzen älterer Menschen wurde jedoch bei der Planung von städtischen Grünflächen bislang wenig Aufmerksamkeit gewidmet. Zu Beginn dieser Forschungsarbeit war das Wissen über die spezifischen Präferenzen älterer Menschen für Grünflächen noch sehr zerstreut und nicht planungsrelevant zusammengeführt und interpretiert. Nur wenige Studien haben versucht, ein systematisches Verständnis der NE-Präferenzen älterer Menschen für verschiedene Arten von Grünflächen zu erlangen oder für Unterschiede zwischen den Präferenzen älterer und junger Gruppen. Zweitens war unklar, ob und wie NE-Möglichkeiten einer Stadt für ältere Menschen im Raumzusammenhang bewertet werden können, um für eine Planung, die Ältere stärker berücksichtigt, eine Grundlage zu schaffen. Drittens wurde die ältere Bevölkerung trotz zunehmender wissenschaftlicher Aufmerksamkeit für Fragen der Umweltgerechtigkeit nicht ausreichend berücksichtigt, insbesondere im Hinblick auf den Zugang und die Zugänglichkeit städtischer Grünflächen.

Um die identifizierten Wissenslücken zu schließen, zielt diese Arbeit darauf ab, ein systematisches Verständnis der Präferenzen älterer Menschen für NE zu liefern, die Möglichkeiten und Nachfragen von NE räumlich zu bewerten und die Gleichheit des Zugangs zu NE für ältere Menschen zu untersuchen. Die Arbeit wird durch die folgenden Forschungsfragen strukturiert: (1) Welche Landschaftsmerkmale und Grünflächenmerkmale werden von älteren Menschen bevorzugt? (2) Welche Erholungspotenziale sowie Möglichkeiten für und Anforderungen älterer Menschen an

NE gibt es im Stadtgebiet Hannover?“ (3) Wie gleichberechtigt ist der Zugang älterer Menschen zu Grünflächen in Hannover auf Quartiersebene.

Für das erste Ziel – den Nachweis von Präferenzen zu synthetisieren – wurde eine systematische Literaturrecherche nach dem „Preferred Reporting Items for Systematic Reviews and Meta-Analyses“-Ansatz durchgeführt. In diesem Review wurden 44 Peer-Review-Artikel analysiert, die zwischen 2000 und 2017 veröffentlicht wurden. Die Ergebnisse bilden einen Rahmen von Faktoren hinsichtlich der Präferenzen älterer Menschen. Der Rahmen besteht aus vier Kategorien: Landschaftselemente (z.B. Ästhetik, Lesbarkeit und kulturelles Erbe), Infrastruktur und Einrichtungen (z.B. Wege, Freizeiteinrichtungen und Geschäftsräume), Instandhaltung (z.B. Sauberkeit und Sicherheit) sowie Zugänglichkeit.

Für das zweite Ziel – der Kartierung von NE-Möglichkeiten – wurde ein räumliches Modell erstellt, basierend auf dem ESTIMAP-Erholungsmodell. Das angepasste Modell berücksichtigte Sonderfaktoren und -parameter, um die Präferenzen älterer Menschen für NE im städtischen Maßstab besser zu integrieren. Es bewertete NE-Möglichkeiten unter Berücksichtigung der Landschaftsästhetik, verschiedener Arten von Einrichtungen und der Nähe. Die Ergebnisse einer Fallstudie in Hannover zeigten, dass die Stadt zwar über viele Stadtparks verfügt, aber nur Teile davon hohe Erholungsmöglichkeiten für ältere Menschen bieten. Orte mit erhöhten Möglichkeiten finden sich vor allem in der Nähe eines Sees im südlichen Stadtgebiet und in den städtischen Wäldern im Nordosten, während eine hohe Nachfrage hauptsächlich in einem Streifen von Wohngebieten im Bereich des Stadtzentrums zu finden ist.

Für das dritte Ziel – der Bewertung der Gleichheit des Zugangs zu städtischen Grünflächen – wurde ein verbesserter „two-step floating catchment area“ (2SFCA)-Ansatz zur Messung der Grünflächen pro Kopf entwickelt. Dieser verbesserte Ansatz berücksichtigte die Attraktivität von Grünflächen, das gegenwärtige Straßennetz und Crowding-Probleme. Es wurden zwei Szenarien getestet, die zwei Mobilitätsstufen in Bezug auf ältere Menschen und die gesamte Bevölkerung darstellten. Die Ergebnisse zeigten, dass im Szenario der „moderaten Mobilität“ (für ältere Menschen) der Pro-Kopf-Wert in jeder Erhebungseinheit geringer ist als im Szenario der „besseren Mobilität“ (für die allgemeine Bevölkerung). Das Szenario „moderate Mobilität“ zeigte eine ungleichmäßigere Verteilung der Zugänge auf die Bezirke Hannovers. Die

bivariate Korrelationsanalyse zeigte keine Hinweise darauf, dass Volkszählungseinheiten mit einem höheren Anteil der älteren Bevölkerung unter einem schlechteren Zugang zu städtischen Grünflächen leiden.

Diese Forschung lieferte ein systematisches Verständnis der Präferenzen älterer Menschen für NE und Ansätze zu deren räumlicher Bewertung. Basierend auf den Ergebnissen wurden folgende Planungsempfehlungen zur Berücksichtigung der Präferenzen älterer Menschen bei der Entwicklung städtischer Grünflächen vorgeschlagen: (1) Eine räumliche Bewertung der Präferenzen älterer Menschen kann dazu beitragen, eine Grundlage für die Grünraumplanung zu schaffen. (2) Die Verteilung der städtischen Grünflächen sollte optimiert werden, um den Bedürfnissen älterer Menschen gerecht zu werden und Ungleichheiten beim Zugang zu Gebieten mit hohem Erholungswert abzubauen. (3) Einrichtungen und Infrastrukturen sind für die Entwicklung des städtischen Grünraums von entscheidender Bedeutung. Viele Grünflächen sind ästhetisch hochwertig und ihr NE-Potenzial kann durch die Verbesserung von Einrichtungen und Infrastrukturen besser genutzt werden. Zukünftige Studien werden vorgeschlagen, um genauer zu untersuchen, wie sich kulturelle Kontexte auf die Präferenzen älterer Menschen für NE auswirken und um die zeitliche und räumliche Dynamik des demografischen Wandels bei der Planung von Grünflächen zu berücksichtigen.

Schlagworte: Ältere Menschen, Naturnahe Erholung, Landschaftsplanung, Öffentliche Gesundheit

CHAPTER 1. INTRODUCTION

1.1 Background

1.1.1 Planning urban green spaces for population aging

In recent years, many European countries have been undergoing a process of population aging. In 27 EU countries, the median age of the population increased from 40.1 years old in 2007 to 42.8 years old in 2017 (EUROSTAT, 2015). Meanwhile, the percentage of people aged 65 or above in the total population increased from 16.9% in 2007 to 19.4% in 2017. Germany is considered one of the countries with a high share of elderly population and will face a serious population aging problem in the near future (EUROSTAT, 2015; Federal Statistical Office, 2009). In 2007, Germany's percentage of people aged above 65 was already 19.8%. This percentage increased to 21.2% in 2017 and is expected to surge to about 30% in 2030.

The demographic structure of many cities has been characterized by population aging. Together with urbanization and social development, in which people migrate from rural areas to urban areas, a growing number of the elderly population lives in cities (United Nations, 2015). In 2015, globally, 60% of people aged 60 or above lived in urban areas, a rapid growth from around 50% in 2000. In Berlin, Germany's capital city, the percentage of people aged above 65 rose from less than 15% in 1990 to around 20% in 2015, resulting in hundreds of thousands more elderly people living in urban areas (Statistisches Bundesamt, 2016).

Population aging has challenged landscape and urban planning with a series of tasks, including employment, housing, social care, public health, and social inclusion (Alidoust & Bosman, 2015; Pleson et al., 2014; United Nations, 2015). Among these tasks, improving urban green spaces to meet elderly people's demand for NBR is considered essential for their quality of life. Leisure activities in nature play a role in affecting elderly people's well-being (Bell, Phoenix, Lovell, & Wheeler, 2014; Lee & Maheswaran, 2011; Takemi Sugiyama & Thompson, 2007). By visiting, sightseeing, or doing physical activities in nature, elderly people can improve their physical and mental health, sense of pleasure, and social contact (Kessel et al., 2009; Lee & Maheswaran, 2011; Ward Thompson & Aspinall, 2011). NBR also helps to relieve stress (Hung &and Crompton, 2006; Kemperman & and Timmermans, 2014; Milligan

et al., 2004) and enhance a sense of community (Matsuoka & Kaplan, 2008; Phillips, Walford, & Hockey, 2011).

However, urban green spaces are not always adapted for elderly people's characteristics. Compared to younger groups, the elderly might suffer from a gradual decline in physical functions and mental health as well as a shrinkage in mobility and social contact (Rosso, Auchincloss, & Michael, 2011). They can be sensitive to environmental barriers, safety issues, and the access to public amenities like green spaces and parks (Rosso et al., 2011; van Hoof, Kazak, Perek-Białas, & Peek, 2018; Yen, Flood, Thompson, Anderson, & Wong, 2014). In urban green spaces development, planners should consider elderly people's needs for health, safety, and social inclusion in a systematic manner (World Health Organization, 2007).

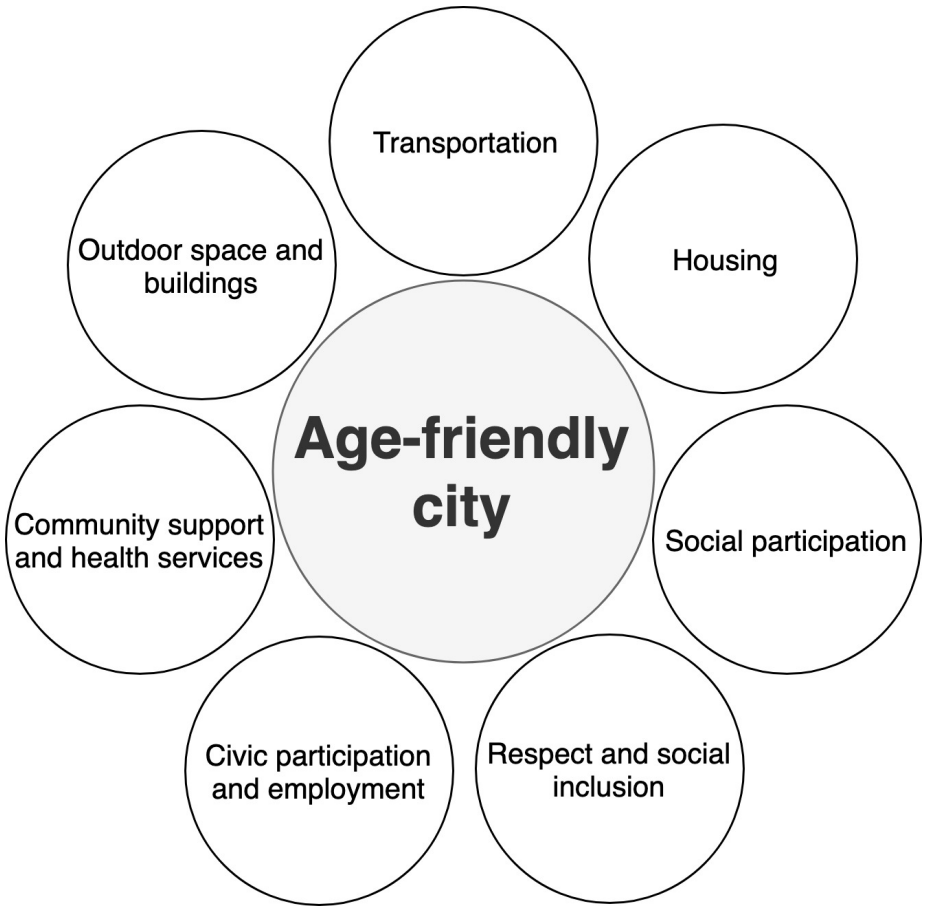


Figure 1-1 Components of an age-friendly city (World Health Organization, 2007)

There are planning guides for developing elderly-friendly cities. The World Health Organization published a well-known planning guideline titled "Global age-friendly

cities" (World Health Organization, 2007), which proposes frameworks to address the principles of "active-aging" (see Figure 1-1). To achieve these goals, practitioners need to address transportation, housing, social inclusion, and buildings and outdoor spaces (World Health Organization, 2007). Similar planning frameworks have emphasized mobility, health, and participation for elderly people in a range of urban neighborhood environments (City of Merritt, 2016; Yen et al., 2014). Elderly people want to be active and healthy, and they should be able to enjoy urban settings that are protective, respectful, and inclusive (Fernández-Ballesteros, Robine, Walker, & Kalache, 2013).

However, relevant planning frameworks for addressing elderly people's NBR are scattered and unsystematic, especially from the perspective of landscape planning. As a systematic practice of safeguarding nature conservation and sustainable development, landscape planning can contribute to human wellbeing in response to social changes (Albert & Von Haaren, 2014; Von Haaren, 2002). Considering urban green spaces as green infrastructure, planning and managing green spaces can improve people's aesthetic appreciation, social contact, and NBR at the city scale (Kabisch & Haase, 2014; Matsuoka & Kaplan, 2008). Various researchers have proposed frameworks for developing elderly-friendly parks (Loukaitou-Sideris, Levy-Storms, Chen, & Brozen, 2016). Additionally, designing and managing recommendations for elderly people are often related to particular features of green spaces, such as therapeutic landscapes (Finlay, Franke, McKay, & Sims-Gould, 2015), accessibility (Barbosa et al., 2007), and social contact (A. Kemperman & Timmermans, 2014).

When considering developing urban green infrastructure, there is little knowledge available on creating elderly-friendly green spaces as a system at the city scale or larger. The development approach for green infrastructure differs from those for designing individual parks or gardens in several key aspects (von Haaren, Warren-Kretzschmar, Milos, & Werthmann, 2014). First, landscape planning for green infrastructure involves a comprehensive evaluation of public interests and preferences. In this context, elderly people may have various NBR needs in different types of urban green spaces (Kabisch & Haase, 2014). Second, landscape planning often requires an analytic process to assess and measure landscape functions and demands (Albert, Zimmermann, Knieling, & von Haaren, 2012; von Haaren et al., 2014; Wolff, Schulp, & Verburg, 2015). To plan for

elderly people at the city scale or larger, it is necessary to understand their preferences in a way on which planners can base their decision-making.

1.1.2 Understanding elderly people's preferences for NBR

So far, most studies that have investigated elderly people's NBR can be categorized as the following types:

- Demonstrating the benefits of nature (e.g. Bell, Phoenix, Lovell, & Wheeler, 2014; Lee & Maheswaran, 2011; Sugiyama & Thompson, 2007).
- Investigating park use (e.g. Tinsley, Tinsley, & Croskeys, 2002).
- Analyzing the relationship between environmental features and physical activity (e.g. Ester Cerin, Sit, Barnett, Cheung, & Chan, 2013; Kaczynski, Johnson, & Saelens, 2010).
- Understanding the perceptions of particular environment features (such as parks, greenery in nursing homes, walkways) (e.g. Alves et al., 2008; Aspinall et al., 2010; Rodiek & Fried, 2005).

In this regard, only scattered knowledge is available regarding elderly people's specific preferences for green spaces. A systematic understanding of their preferences for NBR, including different types of green spaces, landscape characteristics, and the difference in preferences between elderly people and younger groups, has seldom been studied.

In addition, it is critical to understand elderly people's needs for NBR in a spatially explicit way. At the city scale especially, assessing and mapping different NBR conditions can help with better understanding the urban structure and communicating the spatial information of NBR to decision-makers (Casado-Arzuaga, Onaindia, Madariaga, & Verburg, 2013; Maes et al., 2015). Due to the rapid development of concepts in ecosystem services and environmental justice, there are promising tools to analyze and map specific groups of people's needs in planning (Albert, Aronson, Fürst, & Opdam, 2014; Kabisch & Haase, 2014; van den Bosch & Ode Sang, 2017; Wolch, Byrne, & Newell, 2014). For instance, by mapping the different NBR conditions and demands of the people in a certain place, planners can obtain a better understanding of how people interact with nature for wellbeing (Albert et al., 2016; Ekkel & de Vries, 2017). However, elderly people are seldom studied in terms of spatially assessing NBR.

1.1.3 Challenges and knowledge gaps

Despite the expectation, the challenges are threefold. First, apart from studies that have reviewed human-nature interactions, benefits, and physical activity related to urban green spaces (van den Berg et al., 2015; Yen et al., 2014), few studies have synthesized evidence concerning how elderly people perform NBR and what environmental attributes they prefer. When elderly people across different contexts have different interactions with nature, they may have diverse interests in green spaces. A lack of systematic understanding of preferences may lead to a failure to stress stakeholders' needs in green space planning.

Second, while existing spatial models are helpful in assessing recreation potential and opportunities to inform planning, there is little knowledge on developing proper indicators to reflect elderly people's needs and preferences. Existing studies that have assessed NBR often applied different model components and indicators with regard to respective research contexts (Baró et al., 2016; Cortinovis, Zulian, & Geneletti, 2018; Vallecillo, La Notte, Zulian, Ferrini, & Maes, 2019). However, so far, few studies have focused on elderly people by considering their specific indicators and model parameters. Elderly people might have different priorities in requirements for environmental attributes as compared to younger groups (Loukaitou-Sideris et al., 2016; Pettebone et al., 2011). Thus, the assessment needs to represent the state of knowledge of elderly people's preferences.

Third, few studies have focused on age perspectives and inequalities when assessing access to NBR. Investigating equality in green space provision is essential to understanding environmental justice with a focus on vulnerable groups (Rigolon, 2016; Xiao, Wang, Li, & Tang, 2017), especially for elderly people who are vulnerable to neighborhood environments and sensitive to walking distances (Rosso et al., 2011). Traditionally, research on spatial disparity in the distribution of urban green spaces has focused more on people's socioeconomic or ethnicity statuses (Dai, 2011; Heckert, 2013; Hoffimann, Barros, & Ribeiro, 2017; Xiao et al., 2017). The knowledge gaps in the assessment regarding elderly people may hinder planners from addressing possible environmental justice issues.

1.2 Research objectives and questions

This thesis aims to provide a systematic understanding of elderly people's preferences for NBR, to spatially assess NBR opportunities and demands, and to investigate the equality in access to NBR for elderly people. It is organized by addressing the following research questions for each of the objectives (Figure 1-2).

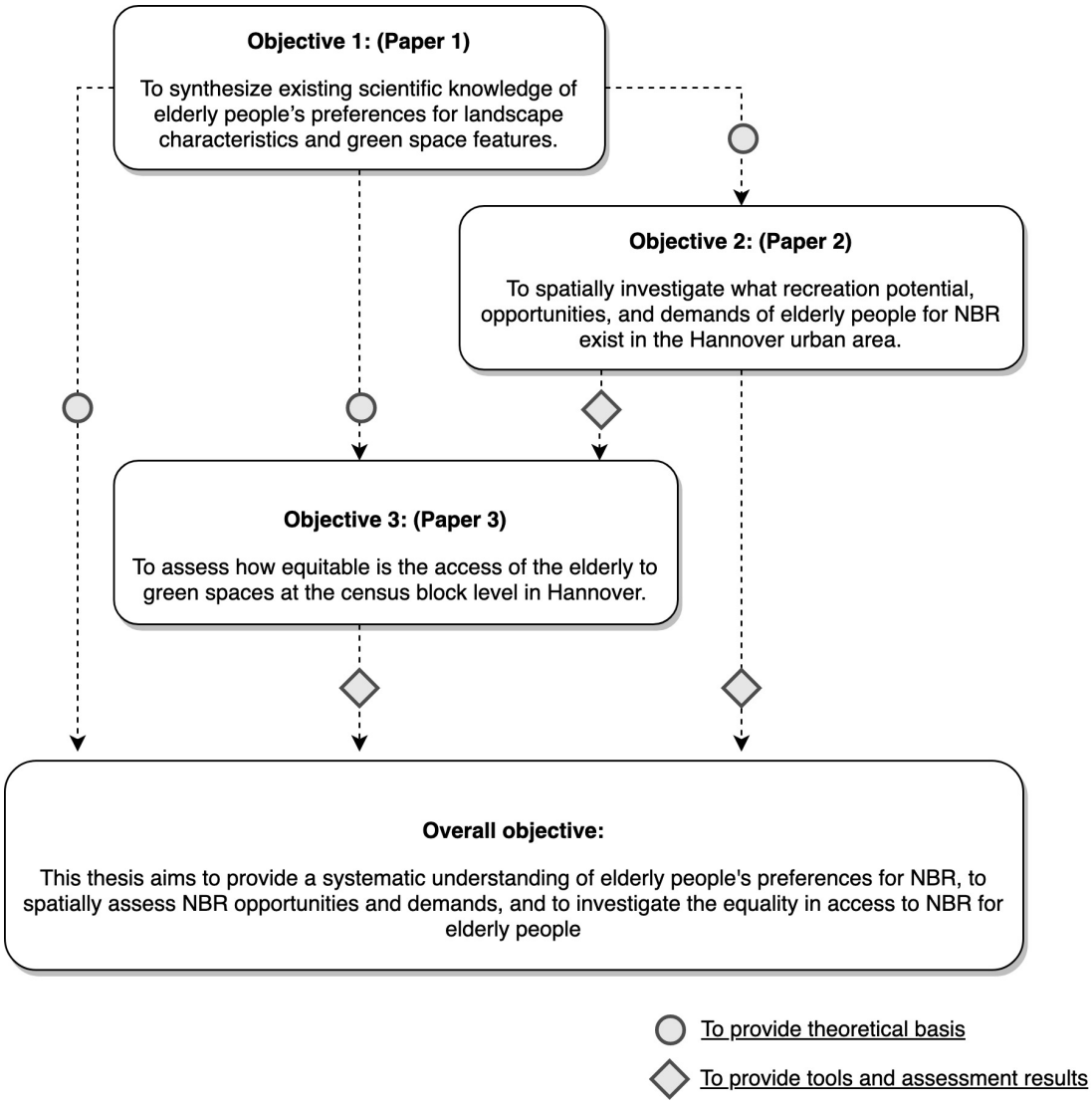


Figure 1-2 Objectives of the thesis

Objective 1: To synthesize existing scientific knowledge of elderly people's preferences for landscape characteristics and green space features.

Research questions regarding Objective 1:

- What landscape characteristics and green space features are preferred by elderly people?
- Are those preferences similar across contexts and interactions?
- How can we improve landscape planning based on the understanding of elderly people's preferences?

Objective 2: To spatially investigate what recreation potential, opportunities, and demands of elderly people for NBR exist in the Hannover urban area.

Research questions regarding Objective 2:

- What recreation potentials, opportunities, and demands of elderly people for NBR exist in the Hannover urban area?
- How are elderly people's demands for NBR met or unmet given the current urban structure?

Objective 3: To assess how equitable is the access of the elderly to green spaces at the census block level in Hannover.

Research questions regarding Objective 3:

- How are green spaces distributed across the study area, considering quantity and quality?
- How equitable is the access to urban green spaces at the census block level in Hannover?
- Does any relationship exist between the share of the elderly population in a census block and its access to green space?

1.3 Elaboration of key terms

Elderly people:

The term "elderly people" is understandable in communication but somehow vague in definition. It is a synonym of other terms such as "older adults", "senior citizens", and "pensioners". The word "elderly" roughly refers to a life stage of "being past middle age", as defined in the Merriam-Webster dictionary, and is often related to changes in

people's physical, psychological, or social dynamics (World Health Organization, 2002). However, there is no widely accepted definition of elderly people (World Health Organization, 2002; Yang & Lee, 2010). Aging is a natural gradual process, and individuals are different in the rate of aging. Even adults of the same age may differ in health status and physical abilities (Yang & Lee, 2010). Moreover, labeling or judging an elderly person is unnecessary at the individual level. Instead of "elderly person", the term "elderly people" makes more sense because it refers to a social group. From a social science perspective, defining the elderly considers not only chronological age but also physical, mental, and social conditions (Orimo et al., 2006; World Health Organization, 2002). Surveys in Japan have studied public awareness of the elderly, and related indicators included retirement status, the need for nursing care, and pension (Orimo et al., 2006).

The definition of elderly people is often used in census statistics and civil administrations, such as social welfare systems and law enforcement. In Germany, the federal statistical office regularly updates current demographic reports, in which the old-age group usually refers to people over 65 (Federal Statistical Office, 2018; Pötzsch & Rößger, 2015). In China, the legal retirement age has been 60 for males and 55 for females for a long time; however, it has been increasing recently (Zeng, 2011).

This thesis adopts the definition of "elderly" as people aged 65 or above. The main reason is that it involves case studies in Germany and has referenced local census data sets, which classify the older group as people aged 65 and above.

Urban green spaces:

Throughout the thesis, the term "urban green spaces" is frequently used. It has diverse meanings in different contexts (Lachowycz & Jones, 2013; Taylor & Hochuli, 2017). For ecosystems and biodiversity, urban green spaces represent a systematic process of land cover, ownership, size, and ecological conditions (Taylor & Hochuli, 2017). For NBR, they are the physical places in which people do recreation to gain health and other benefits (Lachowycz & Jones, 2013; Loukaitou-Sideris et al., 2016). The term in this thesis refers to any open natural or built vegetated lands that provide opportunities for NBR (Taylor & Hochuli, 2017). These areas are often covered by trees, grass, woods, and flowers (Taylor & Hochuli, 2017). In urban settings, green spaces include forests,

wetlands, parks, gardens, and urban squares decorated with canopies (Braquinho et al., 2015). The size of urban green spaces can range from pocket green spaces to urban forests that occupy one or several city blocks. Since this thesis focuses on elderly people's NBR, green spaces that offer limited recreational opportunities have been excluded from the research scope. The excluded types are (1) only for production use without considering recreational use or (2) not publicly accessible.

Nature-based recreation:

The term "nature-based recreation" refers to people's various leisure activities in green spaces (Cortinovis et al., 2018; Ward Thompson & Aspinall, 2011). Compared to other sorts of recreation, such as indoor or electronic entertainment, "nature-based recreation" emphasizes outdoor physical activity, exposure to nature, and an active lifestyle (Horowitz & Vanner, 2010; Neuvonen, Sievänen, Tönnes, & Koskela, 2007).

Depending on the type of green space, NBR may consist of many activities, including, but not limited to, walking, jogging, ball gaming, fishing, biking, or even sedentary leisure such as having a picnic or just sitting and sightseeing (Neuvonen et al., 2007). Although NBR itself is a type of ecosystem service, it provides access to other cultural services, such as a sense of community, spiritual enrichment, and social contact with people (Hernández-Morcillo, Plieninger, & Bieling, 2013; A. Kemperman & Timmermans, 2014). The term "nature-based recreation" in this thesis will be used in a broad sense that refers to any recreational and social activities happening in green spaces.

Recreation potential, opportunities, and demands

Recreation potential, opportunities, and demands are vital concepts in studying NBR from the perspective of cultural ecosystem services (Cortinovis et al., 2018; Paracchini et al., 2014; Zulian, Paracchini, Maes, & Liquete Garcia, 2013). These terms have conceptualized different aspects of NBR and provided standardized tools to assess the landscape.

Recreation potential refers to the capacity of naturalness with a focus on biophysical characteristics for recreational use and landscape aesthetics (Hermes, Albert, & von Haaren, 2018; van Zanten, Verburg, Scholte, & Tieskens, 2016). Recreation demands

refer to the location and quantity of local residents that have needs for NBR. It is often indicated by population hotspots or a proxy for visits and uses (see the review by Wolff, Schulp, & Verburg, 2015). Moreover, recreation opportunities refer to the different suitability for recreation based on multi-criteria conditions, such as aesthetics, accessibility, and facilities (Baró et al., 2016; Grêt-Regamey, Weibel, Kienast, Rabe, & Zulian, 2015; Paracchini et al., 2014; Vallecillo et al., 2019).

Equality in access to green spaces

"Access to green spaces" in this thesis is defined as the quantities of green spaces that people in a spatial unit can reach under a given condition (e.g. a distance or time threshold). By considering urban green spaces as a sort of public resource, the concept of access to green spaces helps in understanding and measuring people's possibilities of enjoying the amenities of NBR (Rigolon, 2016). The term "equality" refers to whether people living in different locations experience a disparity in access to green spaces (Rigolon, Browning, Lee, & Shin, 2018).

Traditionally, studies on equality of access to green spaces have focused more on the spatial disparity between green space provision and people's socioeconomic or ethnicity statuses (Dai, 2011; Heckert, 2013; Hoffimann et al., 2017; Xiao et al., 2017). Meanwhile, there has been growing attention towards the gender and age perspectives (Comber, Brunsdon, & Green, 2008; Dai, 2011; Kabisch & Haase, 2014; Rigolon, 2017). Various studies have found that elderly people are less physically active and less engaged in NBR than younger groups (Lee & Maheswaran, 2011; Milanović et al., 2013; Payne, Mowen, & Orsega-Smith, 2002; Pleson et al., 2014). In this regard, investigating equality in green space provision for elderly people is essential in understanding environmental justice with a focus on vulnerable groups.

1.4 Methodological framework

The methodological framework is organized around each of the objectives (see Table 1-1).

Table 1-1 Methodological framework of the thesis

	Paper 1	Paper 2	Paper 3
Objective	To synthesize existing scientific knowledge of elderly people's preferences for landscape characteristics and green space features.	To spatially investigate what recreation potential, opportunities, and demands of elderly people for NBR exist in the Hannover urban area.	To assess how equitable is the access of the elderly to green spaces in Hannover.
Key method	A systematic literature review was conducted based on the PRISMA method and multi-inclusion criteria.	An adapted ESTIMAP recreation model was used to assess recreation potential, opportunities, and demands based on elderly people's preferences for NBR.	An enhanced version of the 2SFCA method was used to measure access to green spaces by considering green space quantity and quality.
Data collection	Journal papers that were indexed in Web of Science and Scopus within a certain time span.	Demographic statistics; GIS data of land use, natural habitats, facilities, and others.	Demographic statistics; GIS data of land use, natural habitats, facilities, and others.
Data analysis	Quantitative analysis according to the PRISMA procedures; descriptive statistics.	Model building based on the ESTIMAP recreation model; descriptive statistics.	Model building based on the 2SFCA approach; descriptive statistics; inferential statistics.

In Paper 1, which aims at synthesizing evidence of elderly people's preferences for landscape characteristics, a systematic literature review was applied according to the PRISMA method (Moher et al., 2009). The PRISMA method is a standardized framework of procedures to improve the quality of reviews by providing a template checklist (Liberati et al., 2009). The checklist starts by identifying all relevant journal articles in databases; it then excludes duplicate and irrelevant articles according to pre-defined inclusion criteria step by step. It reduces sampling bias and makes every step transparent and reproducible (Liberati et al., 2009). In this study, English papers that were indexed in the Web of Science and Scopus within a certain time span were selected, and evidence of elderly people's preferences for landscape characteristics was then summarized and categorized.

Paper 2 aims at spatially investigating what recreation potential, opportunities, and demands of elderly people for NBR exist in the Hannover urban area. The paper built a model to map recreation opportunities by adapting the ESTIMAP recreation model

(Cortinovis et al., 2018; Paracchini et al., 2014; Zulian et al., 2013). The adapted model considered special factors and parameters to reflect elderly people's preferences for NBR at the city scale. It assessed NBR potential by considering landscape aesthetics, various types of facilities, and proximity. It referred to the street network to understand elderly people's walking behaviors related to urban green spaces. A case study in Hannover, Germany, demonstrated the applicability of the method.

Paper 3 aims at assessing how equitable is the access of the elderly to green spaces in Hannover. Based on the 2SFCA approach (Dai, 2011; Luo & Qi, 2009), this study advanced the model of measuring the value of per capita green space by considering green space attractiveness, street networks, and crowding issues. With a case study in Hannover, this study tested two scenarios regarding different mobility levels to understand access to green spaces, attempting to represent elderly people and the general population. The Gini coefficient and a correlation analysis were performed to test the results.

1.5 Structure of the thesis

This thesis consists of five chapters. Chapter 1 introduces the background and objectives of the thesis and also establishes brief contexts for understanding relevant terms and the theoretical basis. Chapters 2, 3, and 4 respectively describe the efforts and results aimed at achieving the three predefined objectives of this thesis. Specifically, Chapter 2 explores elderly people's preferences and needs for landscape characteristics in different contexts through a systematic literature review of peer-reviewed journal papers. The results helped to base planning recommendations on key environmental features and to guide further model building. Chapter 3 elaborates a framework to spatially assess NBR potential and opportunities for elderly people. With a case study, the framework demonstrated its applicability to support decision-making. Chapter 4 is a study of access to urban green spaces, with a focus on environmental justice from an age perspective. Chapter 5 is a summary of this thesis and an explanation of how the knowledge gaps are closed by achieving research objectives. Limitations and future directions are provided at the end of the thesis.

The thesis is cumulative, and all publications of the thesis are listed in Table 1-2.

Table 1-2 Publications of the thesis

No.	Bibliography	Status	Author Contributions
Paper 1	Wen, C., Albert, C., & Von Haaren, C. (2018). The elderly in green spaces: Exploring requirements and preferences concerning nature-based recreation. Sustainable Cities and Society, 38, 582–593. https://doi.org/10.1016/j.scs.2018.01.023	Published	Conceptualization, C.W., C.A., C.V.H.; Methodology, C.W.; Data collection and analysis, C.W., Original draft preparation, C.W., Revision and editing, C.W., C.A., C.V.H.; Supervision, C.A., C.V.H.
Paper 2	Wen, C., Albert, C., Von Haaren, C. Exploring nature-based recreation opportunities for elderly people in urban areas: A spatial investigation in Hannover, Germany	Submitted to a peer-reviewed journal	Conceptualization, C.W., C.A., C.V.H.; Methodology, C.W., C.A., C.V.H.; Data collection and analysis, C.W., Original draft preparation, C.W., Revision and editing, C.W., C.A., C.V.H.; Supervision, C.A., C.V.H.
Paper 3	Wen, C., Albert, C., Von Haaren, C. Equality in access to urban green spaces: A case study in Hannover, Germany, with a focus on the elderly population	Submitted to a peer-reviewed journal	Conceptualization, C.W., C.A., C.V.H.; Methodology, C.W.; Data collection and analysis, C.W., Original draft preparation, C.W., Revision and editing, C.W., C.A., C.V.H.; Supervision, C.A., C.V.H.

CHAPTER 2. THE ELDERLY IN GREEN SPACES: EXPLORING REQUIREMENTS AND PREFERENCES CONCERNING NATURE-BASED RECREATION[1]

Abstract

As demographic changes abound, landscape planners should increase their understanding of both elderly people's preferences concerning nature-based recreation and approaches to consider those preferences in planning. This study aims to synthesize existing knowledge about elderly people's preferences, namely, how they interact with green spaces, what landscape characteristics they prefer or dislike, and how practitioners can improve planning to better meet elderly people's needs. A systematic literature review based on the PRISMA method was conducted, including an in-depth analysis of 44 peer-reviewed journal articles. We find that published studies focus primarily on elderly people's recreational activities in urban parks. Across different contexts, elderly people seem to have common preferences: landscape features that are natural, aesthetic, comprehensible, and diverse, with accessible and well-maintained infrastructure and facilities. Moreover, interactions between people and nature may affect the relative importance levels of the preferences. We recommend that landscape planning practitioners consider both scientific evidence and local conditions that could affect elderly people's preferences, and explore the degree to which design options may fulfill these preferences. Further research is needed to explore differences in preferences between urban and rural dwellers, to quantify preferences, and to enhance understanding of elderly people's emotional ties with nature.

Keywords: Elderly; green spaces; preference; accessibility; aesthetics; review

[1] This chapter was published as Wen, C., Albert, C., & Von Haaren, C. (2018). The elderly in green spaces: Exploring requirements and preferences concerning nature-based recreation. Sustainable Cities and Society, 38, 582–593. https://doi.org/10.1016/j.scs.2018.01.023

2.1 Introduction

Demographic change has raised growing concerns in many countries for landscape planners (Anderson & Hussey, 2000; United Nations, 2002, 2015). Since aging is a gradual process of human body function decline (Atkinson et al., 2007), defining 'elderly people' is hard and inaccurate. However, most developed countries have adopted age of 65 as a threshold. Some countries have adopted age 60, and some African countries have even adopted 50, the age roughly following local retirement (World Health Organization, 2002). Many countries are already seeing a larger proportion of elderly people in the total population, and this trend is expected to increase towards the middle of the century (United Nations, 2002). For example, in Japan, the percentage of people over 65 in the total population is expected to rise from 22.5% in 2010 to 29.6% in 2030, and onward to 35.7% in 2050 (Japanese National Institute of Population and Social Security Research, 2002). In Germany, the percentage of people over 65 is expected to increase from 20.7 % in 2009 to 29% in 2030, and then to 31% in 2050 (German Federal Statistical Office, 2009). The shifting age structure challenges landscape planners with the elderly's higher risks for health problems, social isolation, and increasing needs for recreation in green space (Loukaitou-Sideris, Levy-Storms, & Brozen, 2014; World Health Organization, 2007). In response, landscape planners should consider the elderly's specific needs and preferences for nature-based recreation, which refers to any recreational activities in green space supported by natural, cultural and historical resources and infrastructures (Shrestha, Stein, & Clark, 2007).

Nature-based recreation plays a role in improving the elderly's well-being (Bell et al., 2014; Lee & Maheswaran, 2011; Sugiyama & Thompson, 2007). By interacting with green spaces on a daily base, the elderly can garner physical and mental health benefits, pleasure, and active social contacts (Kessel et al., 2009; Lee & Maheswaran, 2011; Ward Thompson & Aspinall, 2011). Walking or bicycling to green spaces can promote physical activity and reduce the odds of obesity; having physical activity can strengthen the bones, muscles, as well as heart and lung function (Lee & Maheswaran, 2011; Pereira et al., 2013; Samawi, 2013). Moreover, the elderly may feel stress relieved when immersed in the quietness of nature (Hung and Crompton, 2006; Kemperman and Timmermans, 2014; Milligan et al, 2004). When sightseeing or gardening in nearby

green space, elderly people can experience an enhanced sense of belonging to local communities (Matsuoka & Kaplan, 2008; Phillips et al., 2011). In urban parks, they can feel motivated to enjoy active social contacts and group activities (Hung & Crompton, 2006). All these benefits of nature-based recreation have a significant influence on elderly people's wellbeing.

In order to help senior citizens garner these wide-ranging benefits, some institutions have published generic planning and design recommendations. The World Health Organization (2007) published a global age-friendly city guideline, recommending that outdoor and green spaces should be barrier-free, attractive, well equipped, and accessible to elderly people. The Lewis Centre for Regional Policy Studies (Loukaitou-Sideris et al., 2014) published guidelines for senior-friendly parks, listing critical design elements that include safety, natural attributes, facilities, physical activities, social support network, and proper age composition (e.g., seniors-only parks to avoid potentially uncomfortable, embarrassing, or frightening interactions with young people). However, apart from studies that review the benefits of green spaces, few studies have synthetized evidence of how elderly people recreate and what environmental attributes they prefer. When elderly people across contexts have different interactions with nature, they may have different expectations of and diverse interests in green spaces. A lack of understanding of preferences may lead to a failure to support planning practices which achieve diverse goals and take into consideration the complexity of human nature. The main objective of this paper is to synthesize evidence of the elderly's preferences for landscape characteristics to analyze the similarities and differences in their preferences, and then to make suggestions regarding future landscape planning.

Therefore, the main research questions of this review are:

- What landscape characteristics and green space features are preferred by elderly people?
- Are those preferences similar across contexts and interactions?
- How can we improve landscape planning based on the understanding of elderly people's preferences?

2.2 Theoretical framework

2.2.1 Elderly people's preferences for green spaces

Previous studies defined preference as a cognitive process where some people appreciate a landscape more than another, considering it 'more aesthetic, lively, or desirable' (R. Kaplan, Kaplan, & Brown, 1989; S. Kaplan, 1987). In terms of landscape preference, many studies focused on aesthetics. Theories to explain aesthetic preferences were mainly developed by two schools – the objective approach and the subjective approach (Maulan, Kamal, Shariff, & Miller, 2006). The former considers aesthetics as the internal qualities of a landscape and can be measured objectively; the latter considers people's emotional response which cannot be captured objectively (R. Kaplan et al., 1989; S. Kaplan, 1987; Maulan et al., 2006; Zube, Pitt, & Evans, 1983). In these paradigms of landscape architecture and management, preferences are often believed to be associated not only with landscape characteristics, but also with the way people interact with them, the specific setting of interactions, and the characteristics of people (Dramstad, Tveit, Fjellstad, & Fry, 2006; Hetherington, Daniel, & Brown, 1993; Kaymaz, 2012; Maulan et al., 2006). Our review followed the understanding that landscape preferences are user-dependent, and we developed a theoretical framework (Figure 2-1) to address relationships between elderly people's preferences for nature-based recreation and landscape characteristics, and how the relationships may be explained and moderated.

Elderly people's physical condition and cognition have aged, so they may find some green spaces more attractive than young people would. Some studies found that elderly people liked natural environments more than built environments and visited parks more frequently than young people did (Jorgensen and Anthopoulou, 2007; Kemperman and Timmermans, 2006). Other studies, however, argued that elderly people showed less interest in green spaces compared to young people (Lyons, 1983; Sayan & Karagüzel, 2010).

Empirical studies on the elderly's preferences not only focus on landscape aesthetics but also on other human needs. Relevant studies about needs can be categorized into five interrelated groups:

(1) Green spaces and open spaces that can promote elderly people's walking and other physical activities (see Joseph and Zimring, 2007; Kaczynski et al., 2010).

(2) Parks that can promote participation (see Kemperman and Timmermans, 2006).

(3) Green spaces that can support social contacts and wellbeing (see Yung et al., 2017; Kemperman and Timmermans, 2014).

(4) Therapeutic gardens and space (see Milligan et al., 2004).

(5) Aesthetic and attractive green spaces (see Alves et al., 2008; Aspinall et al., 2010)

Thus, a green space's possibilities to fulfill needs can be conceptualized as explanations to understand elderly people's preferences for nature-based recreation.

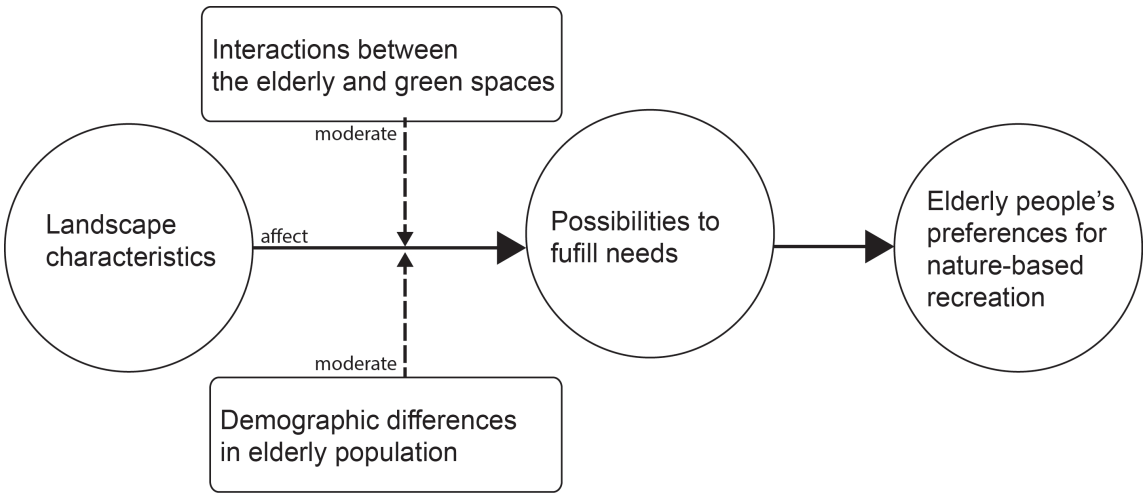


Figure 2-1 Theoretical framework illustrating the relationships between landscape characteristics and elderly people's preferences for nature-based recreation.

2.2.2 Landscape characteristics that affect preferences

For different purposes, some recent studies reviewed or summarized landscape characteristics that affect the elderly's preferences and needs. Yung et al. (2017) proposed a conceptual framework to address design factors that affect the elderly's satisfaction when they visit parks in highly-dense urban districts. The categories in this framework include proximity, accessibility, social inclusion, social connection, supporting facilities, and connection to nature. Yen et al. (2014) reviewed 120 articles to study how environmental attributes affect the elderly's mobility, and they concluded

that safety is the central factor that links other factors such as connectivity, aesthetics and shopping services. Barnett et al. (2017) reviewed 100 articles to study the elderly's physical activities, and they found that safety, walkability, access to parks, natural and aesthetic pleasing scenery, and recreational facilities play roles.

However, previous reviews that synthesized evidence of preferences focused on parks and physical activity, and they seldom considered different types of green spaces and activities that may have required different landscape characteristics. We need to know the general and special preferences. General preferences refer to landscape characteristics that elderly people across contexts like or dislike when they have a range of activities in green spaces. Specific preferences are those only elderly people from certain background prefer, or attributes preferred only in special human-nature interactions. Interactions are explained below.

2.2.3 Interactions and demographic differences as moderators

This review considers that interactions have three aspects - types of green spaces, types of activities, and basic needs to be fulfilled. The term 'green space' can be any type of greenery in urban or rural contexts, including house greenery, neighborhood greenery, institutional greenery, park, garden, grassland, woodland, greenery near sports facilities, and greenery near waterways (Braquinho et al., 2015). The term 'basic needs', according to Max-Neef (1992), includes 'subsistence, protection, affection, understanding, participation, leisure, creativity, identity, and freedom'. Moreover, demographic differences refer to that elderly people may have different demographic characteristics, including socioeconomic status, health conditions, household sizes, and geographic locations (Takano, Nakamura, & Watanabe, 2002). For example, elderly people may use wheelchair or not, live in care facilities or their own homes, suffer from dementia or not. The differences in demographic characteristics and the way they interact with landscape may play a role in moderating preferences for nature-based recreation.

We therefore generated two hypotheses. Firstly, elderly people prefer a green space for nature-based recreation when they have possibilities to fulfill needs. Second, interactions between nature and elderly people moderate the preferences. The two hypotheses in this study were used to elicit answers or understandings regarding research questions; they oriented the study design.

2.3 Methods

We conducted a systematic literature review according to the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009). The PRISMA method of systematic review aims to improve the quality of reviews by establishing a template checklist (see Figure 2-2) (Liberati et al., 2009). The checklist starts by identifying all potential relevant journal articles in databases; it then excludes duplicate and irrelevant articles, and finally focuses on eligible articles. This systematic review method is considered reliable and transparent in analyzing existing scientific evidence regarding a specific research question (Mallett, Hagen-Zanker, Slater, & Duvendack, 2012). It reduces sampling bias by acquiring all available empirical evidence, and it elucidates every step of eligibility criteria that enable other researchers to verify and repeat (Liberati et al., 2009).

Based on three main research questions above, a set of reviewing questions was prepared as follows (Table 2-1). These reviewing questions were used as guidelines for collecting relevant information from each included article.

Table 2-1 Reviewing questions and inclusion criteria

Reviewing questions	Possible relevant information from the literature
What are the specific characteristics regarding elderly people?	Age, whether elderly people are divided into subgroups, whether elderly people are compared with other age groups.
What is the study design?	Research purpose, sample volume, location of the study, method, and data type.
How do elderly people interact with the green space?	Types of green spaces, types of activities, and types of basic needs.
What are the preferences for green spaces?	Prefers or does not prefer the natural features, perceptual features, and cultural features of green spaces.
What role does the context play?	How does the context contribute to variations in preferences?
Inclusion criteria	**Exclusion criteria**
1. Empirical study or original research;	1. Review, report, book chapter, or gray literature
2. Written in English	2. Written in non-English

3. Relevant to key concepts: elderly people over 60 years old, green spaces, short-trip recreation, and preferences.	3. Focus on young adults or children, focus on built environments without any discussion of green spaces, and focus on transnational tourism or long-distance driving tour.
4. Articles accessible	4. Articles inaccessible

In this study, we only included peer-reviewed journal articles to ensure quality of evidence. Two major academic databases—Web of Science and Scopus—were used as search platforms. The two databases are widely used for collecting evidence for practice in landscape architecture and urban planning disciplines (Kabisch, Qureshi, & Haase, 2015). The search was conducted in December 2015 and September 2017, and the time frame of publications was set between January 1, 2000 and December 31, 2017. The reason for starting from January 1, 2000 is that, according to our pilot research, a growing number of relevant studies were published since the beginning of the 21st Century, and we wanted to synthesize evidence that is up-to-date. The language of examined articles was English only. The same search items ("title + abstract + keywords") were searched in each database after the adaptation of search rules. The rule of building search items was "elderly people (and synonyms)" AND "green spaces (and synonyms)" AND "recreation (and synonyms)" AND "landscape characteristics (and synonyms)." Detailed search items are listed in Appendix A.

A four-step process was used to select articles (Figure 2-2); those steps were identification, screening, eligibility, and inclusion. The process started from merging search results from different databases, excluding duplicates, to screening articles by reading titles, abstracts, and full-texts. Table 2-1 shows the criteria and exclusion criteria. After the process, 38 articles were included. Additionally, another six articles that appeared relevant, but were not in the search results were manually added. To ensure the quality of evidence, a set of criteria was used to check whether the sample was described, the measurement was defined, and any bias was addressed (Lee & Maheswaran, 2011; Walshe & Rundall, 2001). All 44 articles passed the appraisal and were included in this review.

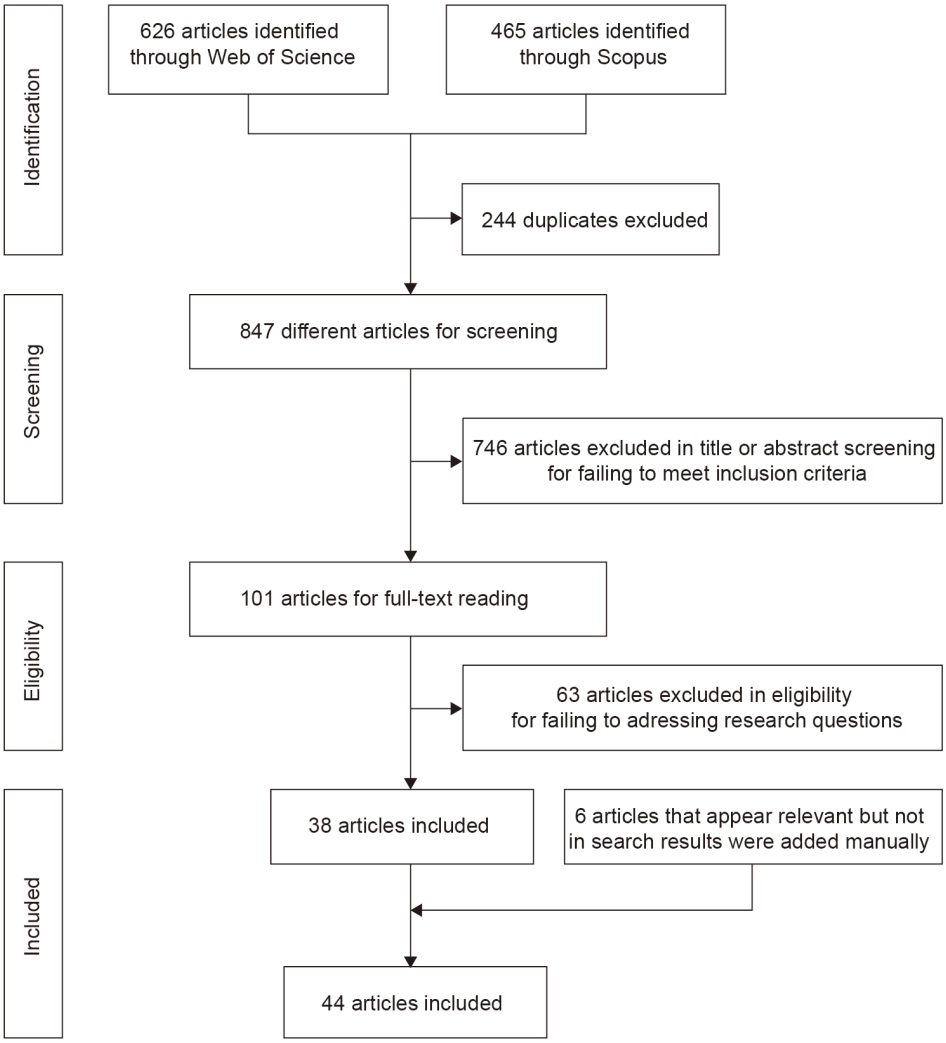


Figure 2-2 Workflow of the systematic literature search of this paper, based on the PRISMA approach (Moher et al., 2009).

2.4 Results

2.4.1 General information about included articles

We reviewed 44 peer-reviewed articles (see Appendix A) from a variety of journals. Locations of these studies cover Europe, North America, South America, Australasia, and Asia, but not Africa. More than half of the studies relate to Europe and North America, and the United Kingdom and the United States are the countries with the most studies.

Studies investigated the elderly's activities and preferences for nature-based recreation with various methods (Figure 2-3). Most of them used quantitative data, and some used both quantitative and qualitative data. The questionnaire method was used most frequently to collect data. Many studies designed questionnaires to serve particular

research purposes (Artmann et al., 2017; Eronen et al., 2013; Hung and Crompton, 2006; Jorgensen and Anthopoulou, 2007; Kaczynski et al., 2008; Parra et al., 2010; Yilmaz et al., 2011). Some studies used standardized questionnaires such as PAQ, CHAMPS and EPIporto PA to survey physical activity (Cerin, Lee, et al., 2013; Cerin, Macfarlane, et al., 2013; Cerin, Sit, et al., 2013; Joseph & Zimring, 2007; Ribeiro, Mitchell, Carvalho, & de Pina, 2013; T Sugiyama, Leslie, Giles-Corti, & Owen, 2008). One study used public-participation GIS method to collect information on people's preferred locations (Laatikainen, Broberg, & Kyttä, 2017). Researchers also widely used observational and experimental methods to analyze park use. Relevant methods included multi-week observation (Kaczynski, Stanis, Hastmann, & Besenyi, 2011; Zhai & Baran, 2016), image-based simulation (photo or Visual Reality) (Phillips, Walford, Hockey, Foreman, & Lewis, 2013; Rodiek & Fried, 2005), and choice-based analysis that detects the relative importance of different landscape characteristics (Aspinall et al., 2010; Pettebone et al., 2011). In a study in the UK, researchers accompanied elderly people with dementia as they walked in an unfamiliar environment to observe their travel behaviors (Mitchell, Burton, & Raman, 2004). Additionally, researchers used in-depth interviews to investigate the elderly's deep thoughts and attachment to the local landscape. For example, studies encouraged the elderly to talk about the perceived benefits and constraints of visiting green spaces (Yung et al., 2017; Hung and Crompton, 2006; Reynolds, 2016), perceptions on park equipment (Chow, 2013; Ottoni, Sims-Gould, Winters, Heijnen, & McKay, 2016), and opinions about therapeutic landscape and gardening (Leaver & Wiseman, 2016; Milligan et al., 2004).

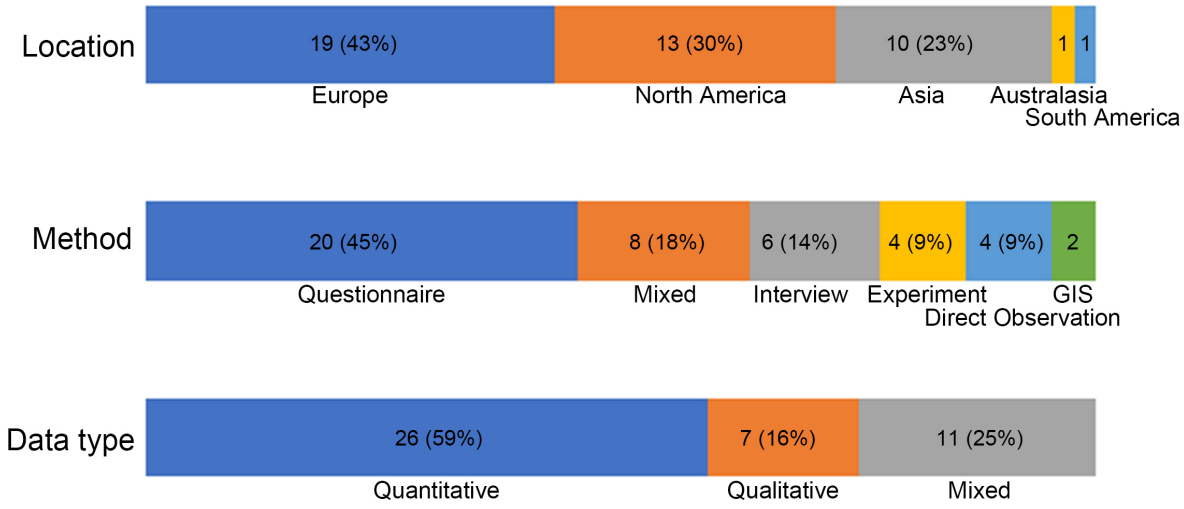


Figure 2-3 Selected characteristics of the 44 papers included in the analysis.

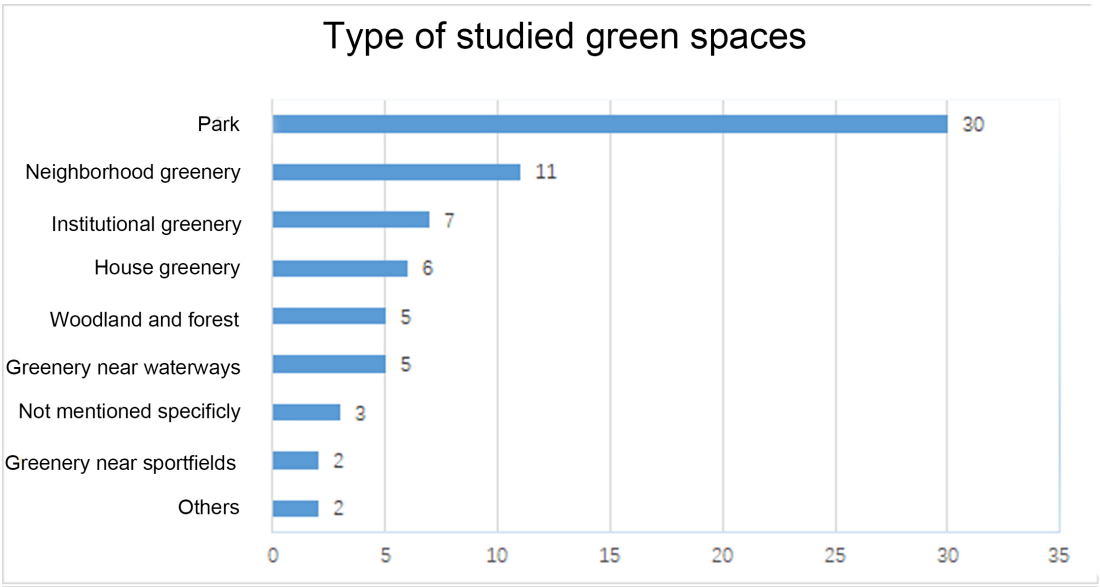
2.4.2 Elderly people's interaction with green spaces

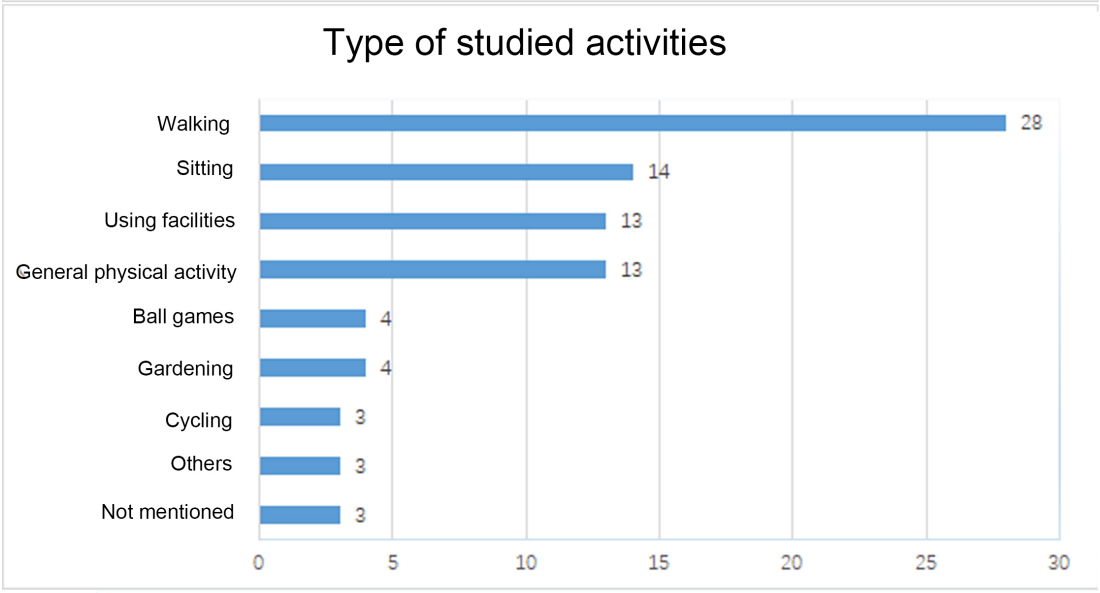
Among various types of green spaces, the most frequently examined types were park (30), followed by neighborhood greenery (11), institutional greenery (7), and house greenery (6) (Figure 2-4). The term "park" had diverse meanings in different studies, and it indicated green spaces of different locations and sizes. For instance, many studies only used the term to indicate general urban parks, but other studies used it to express heritage parks (Jorgensen & Anthopoulou, 2007), national parks (Pettebone et al., 2011), and parks surrounding retirement communities (Hung & Crompton, 2006; Reynolds, 2016). Studies of neighborhood greenery covered street spaces (Cerin et al., 2013a; Parra et al., 2010) and squares with trees (Alves et al., 2008). Some studies investigated yards of nursing homes or allotments near the residence that allowed people to cultivate inside (Leaver & Wiseman, 2016; Milligan et al., 2004; Reynolds, 2016). However, most studies focused on green spaces in urban areas, with only a few examining green space in rural contexts, for example, woodlands or mountain national parks (Pettebone et al., 2011; Vecchiato & Tempesta, 2013). Green spaces in agriculture areas and villages are rarely studied.

Regarding activities, walking (28), sitting (14), facility usage (13), and general physical activity (13) were most frequently examined (Figure 2-4). Studies investigated walking

under various conditions: walking from home to the park, walking in the park, and walking in a residential/institutional yard (Cerin, Sit, et al., 2013; T. W. Chao, Chai, & Juan, 2014; Eronen et al., 2014; Joseph & Zimring, 2007; Zhai & Baran, 2016). One study in the United States addressed the elderly's travel mode (private car or shuttle bus) to the parks based on different scenarios (Pettebone et al., 2011). Some studies used the term "general physical activity" (10) to generalize many activities without emphasizing a particular type (Kaczynski et al., 2010; Ribeiro et al., 2015; Van Cauwenberg et al., 2011). Additionally, several studies stressed sedentary activities in green spaces, mainly sitting, to discern the elderly people's resting, chatting, picnicking, and table gaming (Hung & Crompton, 2006; Tinsley et al., 2002).

Although all of the papers assessed the environment regarding its quality for fulfilling basic needs, some needs were studied more frequently (Figure 2-4). In the perspective of Max-Neef's humans needs matrix (Max-Neef, 1992), our results show that elderly people's subsistence (41), leisure (35), and protection (safety) (24) were most frequently studied. Subsistence was defined as life-supporting needs, which include shelter, toilet, restaurant, and physical activity (Alves et al., 2008; Aspinall et al., 2010; Mitchell et al., 2004). Leisure was exemplified by recreational activity, active relaxing, and social engagement (Hung and Crompton, 2006; Jorgensen and Anthopoulou, 2007; Kemperman and Timmermans, 2014; Ward Thompson and Aspinall, 2011). The protection (safety) need was related to traffic danger, crime, injury, and getting lost (Alves et al., 2008; Aspinall et al., 2010; Hung & Crompton, 2006; Jorgensen & Anthopoulou, 2007; Ward Thompson & Aspinall, 2011). However, only a few studies stressed needs that revealed emotional tie between people and nature, for example, self-identity, religious spirituality, creativity inspired by nature, and past memories triggered by old trees (Leaver & Wiseman, 2016; Milligan et al., 2004; Reynolds, 2016; Tinsley et al., 2002).





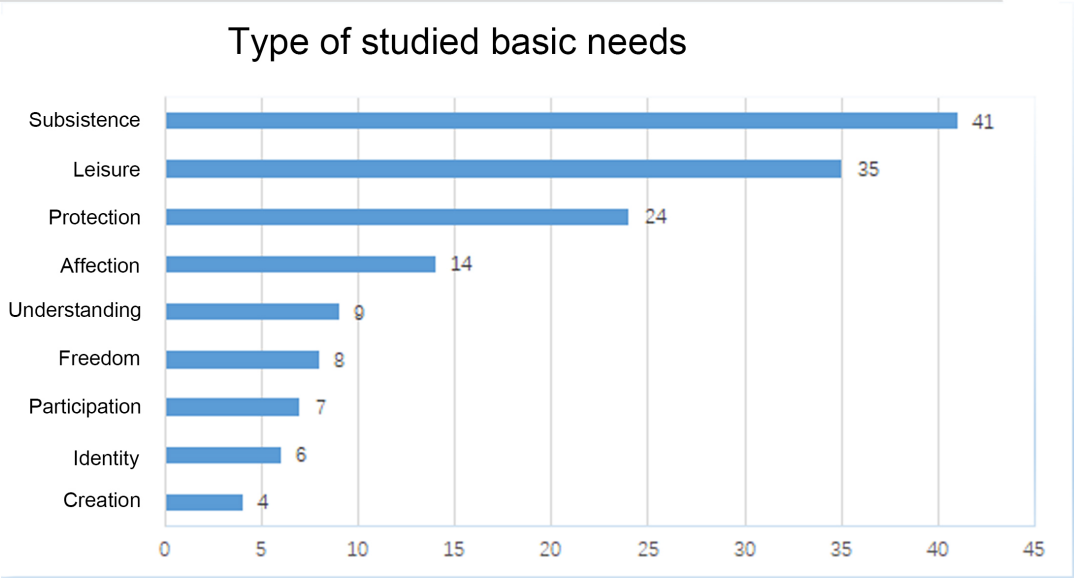


Figure 2-4 Distribution of papers referring to specific types of green spaces, activities, and basic needs (n=44).

2.4.3 Evidence of landscape characteristics that elderly people preferred

Our review found that elderly people across different cultural contexts have common preferences; however, they do exhibit some variations. We categorized elderly people's landscape preferences into four main clusters: landscape features, infrastructure and facilities, maintenance, accessibility (Table 2-2). Each cluster contains several general findings, and some of them contain special preferences. We adapted this categorization from several previous studies but with a balance of the distribution of available evidence (Alves et al., 2008; van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012). Among all subcategories, aesthetics, proximity, and the quality of trails are most studied. Figure 2-5 illustrates some samples of landscape characteristics.

Table 2-2 Evidence of landscape characteristics preferred by elderly people for nature-based recreation.

Categories	Subcategories	Evidence of landscape characteristics for nature-based recreation			
		Number of publications	Core findings of preferences	Source	Notes or special preferences
Landscape features	Aesthetics	21	Naturalness, for example, various sorts of vegetation with varieties in color and height. Wild animals to watch. Attractive architecture or statues. Water features, such as lakes, ponds, and fountains. Open views but with a visual center, which could be a statue, a stone, a water feature, or distinctive plants. Seasonal-changing scenery.	(Alves et al., 2008; Aspinall et al., 2010; Cain et al., 2014; Cerin et al., 2013a, 2013c; Chao et al., 2014; Esther et al., 2017; Gong et al., 2014; Goto and Fritsch, 2011; Hung and Crompton, 2006; Jorgensen and Anthopoulou, 2007; Kemperman and Timmermans, 2014; Leaver and Wiseman, 2016; Milligan et al., 2004; Mitchell et al., 2004; Reynolds, 2016; Rodiek and Fried, 2005; Sugiyama and Ward Thompson, 2008; Tinsley et al., 2002; Vecchiato and Tempesta, 2013; Ward Thompson et al., 2011)	At nursing homes, elderly people like the green spaces surrounded by plants as windbreak rather than high buildings (T. W. Chao et al., 2014). In a peri-urban area of Venice, people prefer the mixed plantation with 75% woodland and 25% meadow to a pure woodland (Vecchiato & Tempesta, 2013). Elderly people with dementia prefer informal spaces with recognizable building features and other people having activities inside; elderly people without dementia prefer formal green spaces with an open view (Mitchell et al., 2004).
	Legibility	5	Predictable environments. Landmarks or distinctive features Map information in the green spaces	(Artmann et al., 2017; Cohen et al., 2009; Jorgensen & Anthopoulou, 2007; Mitchell et al., 2004; Phillips et al., 2013)	Elderly people in unfamiliar environments like signs that only provide essential navigating information rather than signs with massive information (Mitchell et al., 2004; Phillips et al., 2013). The elderly in yards of nursing homes don’t like dense vegetation that hinders vision (Artmann et al., 2017).

	Soundscape and air quality	5	Quietness in the urban greenery. Natural sounds, like birdsongs, and sounds of water and wind. Fresh air, and avoidance from automobile exhaust in urban areas.	(Cerin, Lee, et al., 2013; T. W. Chao et al., 2014; Hung & Crompton, 2006; Milligan et al., 2004; Phillips et al., 2013)	Elderly people living in highly-dense urban areas prefer the quietness and clean air in parks (Cerin, Lee, et al., 2013; Hung & Crompton, 2006)
	Sunshine and shade	6	Having canopies and shades in summer, and places for enjoying the sunshine in winter.	(T. W. Chao et al., 2014; Milligan et al., 2004; Rodiek & Fried, 2005; Zhai & Baran, 2016)	
	Cultural heritages	2	Worship places in green spaces, like church. Green spaces with cultural heritage, festival activities, or traditional atmosphere.	(Jorgensen & Anthopoulou, 2007; Ribeiro et al., 2015)	The elderly like old urban woodlands that remind of their past (Jorgensen & Anthopoulou, 2007).
Infrastructure and facilities	Trails	18	Pavements with anti-slip and water-resistant material. Barrier free and the slope less than 5%. Long, continuous, and curved trails in the parks for recreational walking. Well-designed paths connecting different interesting parts of green spaces. Trails without crowds and collisions.	(Artmann et al., 2017; Cerin et al., 2013a, 2013b, 2013c; Chao et al., 2014; Chow, 2013; Eronen et al., 2013; Hung and Crompton, 2006; Jorgensen and Anthopoulou, 2007; Joseph and Zimring, 2007; Kaczynski et al., 2014, 2008; Mitchell et al., 2004; Parra et al., 2010; Phillips et al., 2013; Rodiek and Fried, 2005; Tinsley et al., 2002; Zhai and Baran, 2016)	Elderly people with dementia prefer short, narrow, and well-connected trails for easy comprehension (Mitchell et al., 2004). A study in China revealed that the elderly might like to choose park pathways with no connection to activity zones, possibly for fear of crowds (Zhai & Baran, 2016).
	Intersections	5	Light traffic on roads to the green spaces. Fewer intersections for fear of traffic. The presence of bridges or underground passages for crossing streets.	(Alves et al., 2008; Aspinall et al., 2010; Cerin et al., 2013b, 2013c; Parra et al., 2010)	Many high-income countries report a positive association between the number of intersections and physical activity level while low-income countries report negative association due to high traffic accidents (Parra et al., 2010).

			Traffic lights with enough time for elderly people to cross streets.		In metropolitan Hong Kong, the elderly seem to believe, the more crossroads, the more convenient for them to reach any destinations, including green spaces (Cerin, Macfarlane, et al., 2013).
	Seating	9	Chairs in green spaces, optimally with seatbacks and armrests	(Artmann et al., 2017; Aspinall et al., 2010; Cerin, Lee, et al., 2013; T. W. Chao et al., 2014; Jorgensen & Anthopoulou, 2007; Mitchell et al., 2004; Ottoni et al., 2016; Rodiek & Fried, 2005; Zhai & Baran, 2016)	
	Recreational facilities	11	Access to recreational facilities, such as outdoor exercise equipment, ball game fields, or bicycle trails. Playgrounds for children. Opportunities to perform Do-It-Yourself (DIY) cultivating in some allotments.	(Cerin, Lee, et al., 2013; Cerin, Macfarlane, et al., 2013; Chow, 2013; Cohen et al., 2009; Eronen et al., 2014; Kaczynski et al., 2014, 2010, 2008; A. D. A. M. Kemperman & Timmermans, 2006; Milligan et al., 2004; Takemi Sugiyama & Ward Thompson, 2008)	Elderly people want the recreational facilities with instruction and emergency brake system for avoidance of injury (Chow, 2013) Elderly people do not like to be charged for using park facilities (Cohen et al., 2009) In the DIY cultivating allotments, elderly people want to get help from other elderly peers or professional gardeners (Milligan et al., 2004).
	Business settings and toilets	10	Café and restaurants near green spaces. Toilets.	(Alves et al., 2008; Aspinall et al., 2010; Cerin et al., 2013a, 2013c; Joseph and Zimring, 2007; Kaczynski et al., 2010; Mitchell et al., 2004; Parra et al., 2010; Ribeiro et al., 2015; Ward Thompson et al., 2011)	Commercial areas and mixed land uses can encourage elderly people to go outdoors, but not necessarily to green spaces (Ribeiro et al., 2015). Low land-use diversity and more park facilities may promote physical activity in parks (Kaczynski et al., 2010)
Maintenance	Cleanliness	2	Pavements that are clean of litter, surface water, and fallen leaves.	(Chow, 2013; Eronen et al., 2014)	

			Well-maintained chairs, lights, and exercise facilities		
	Security	11	Green spaces with good visibility and under supervision Avoidance of nuisance, crime, and vandalism. Avoidance of free-running dogs. Lights in green spaces.	(Alves et al., 2008; Artmann et al., 2017; Aspinall et al., 2010; Cerin et al., 2013a; Chao et al., 2014; Esther et al., 2017; Hung and Crompton, 2006; Jorgensen and Anthopoulou, 2007; Kemperman and Timmermans, 2014; Sugiyama and Ward Thompson, 2008; Ward Thompson et al., 2011)	In the outdoor yards of nursing homes, elderly people like lights with various levels of brightness and height for better visibility (T. W. Chao et al., 2014). In yards of nursing homes, the elderly like fences to protect their privacy from being seen from outside (Artmann et al., 2017). In parks and neighborhood open spaces, people are afraid of dogs attacking them (Alves et al., 2008; Aspinall et al., 2010). Interestingly, many elderly people like to walk their own dogs to promote physical activities (A. D. A. M. Kemperman & Timmermans, 2006; Milligan et al., 2004)
Accessibility	The proximity of green spaces	20	Walking distance from home to public green spaces. Street network with good connectivity by which elderly people can easily travel to green spaces from any location. Increasing the number of parks within a certain proximity from home. Small, Informal greenery distributed near home.	(Aspinall et al., 2010; Barbosa et al., 2007; Cerin, Lee, et al., 2013; Cerin, Macfarlane, et al., 2013; Eronen et al., 2014; Esther H.K. et al., 2017; Y. Gong et al., 2014; Hung & Crompton, 2006; Jorgensen & Anthopoulou, 2007; Kaczynski et al., 2014; A. D. A. M. Kemperman & Timmermans, 2006; A. Kemperman & Timmermans, 2014; Laatikainen et al., 2017; Parra, McKenzie, et al., 2010; Ribeiro et al., 2015; Ward Thompson & Aspinall, 2011; Yilmaz et al., 2011; Zhai & Baran, 2016)	In the UK, the recommended distance from home to nearest greenery is less than 300m or 10 minutes' walking (Barbosa et al., 2007; Ward Thompson & Aspinall, 2011). Elderly people prefer more green spaces within 400m from home in the UK (Y. Gong et al., 2014), or within 1 mile from home in the US (Kaczynski et al., 2014) According to a study in Turkey, the poor elderly like to visit parks in the city center near where they live, while the wealthy elderly with cars like the

				green spaces in further sites (Yilmaz et al., 2011).
	Travel modes other than walking	2	Public transportation from home to green spaces. Bicycle trails from home to green spaces or within green spaces.	(Jorgensen & Anthopoulou, 2007; Pettebone et al., 2011)	The elderly prefer to drive cars to national parks in rural areas instead of using public transportation more than young adults do (Pettebone et al., 2011)

Figure 2-5 A sample of elderly-friendly park: Planten un Blomen in Hamburg, Germany. This free park is located near the city center, with easy access for all visitors on foot or by public transportation. It is well-equipped with ramps, barrier-free facilities, and toilets. Green spaces here have a diverse range of plants with different heights and colors. Elderly people can easily find chairs to rest and enjoy the landscape, waterscape, fish, and birds. Occasionally, the park offers free outdoor music concerts and cultural activities. Elderly people may also accompany kids to play on the playgrounds.

2.5 Discussion

2.5.1 Preferences for nature-based recreation

Our results echo some findings from previous studies. Despite diverse cultural backgrounds and purposes, elderly people show common preferences for nature-based recreation. For example, they seem to underline accessibility, safety, physical activity, social contacts, and landscapes that are beautiful and legible (Loukaitou-Sideris et al., 2016; Matsuoka & Kaplan, 2008; Yen et al., 2014). Our review confirms these common preferences and identifies core preferences for nature-based recreation and for variations in landscape characteristics.

Most studies focused on the elderly's walking – either on the way from home to green spaces or within green spaces – in urban areas. The possible reason is that most included studies are from developed countries with high levels of urbanization, and elderly people residing in cities like to visit green spaces near where they live. Globally, almost

60% of elderly people live in urban areas (United Nations, 2015). In developed countries that percentage is even higher; 80% of the elderly are urban dwellers (Yen et al., 2014). Thus, the accessibility of urban green spaces, especially parks, plays a dominant role in affecting the elderly's nature-based recreation. However, focusing primarily on walking and general physical activity may restrict the development of green spaces to their functionality with respect to sports, such as the quality of walking infrastructure or recreational facilities. Many studies focused on aesthetics, but only in the perspective of promoting physical activity and park visitation. They overlooked emotional ties between the elderly and nature, for example, memories and cultural heritage. In this regard, we found that only a few studies investigated the needs of creativity, participation, and freedom. Only two studies focused on gardening in allotments, and they revealed that when elderly people build their own living environment and create social ties with other elderly peers, they feel creative, grateful, and united (Leaver & Wiseman, 2016; Milligan et al., 2004). Additionally, because only a few studies considered villages and agricultural areas or conducted comparisons, it remains unclear whether the preferences of elderly people in urban areas are similar to those in rural areas.

Our review grouped the evidence of preferences for landscape characteristics into four categories – landscape features, infrastructure and facilities, maintenance, and accessibility. Although some core preferences (see Table 2-2) seem to be influential despite contexts, the way elderly people decided to interact with nature does interplay with landscape characteristics. Regarding the types of green spaces, elderly people are more sensitive to the connectivity, air quality, noise, and business settings in neighborhood greenery and informal green spaces; they are more sensitive to the season-changing landscape, open views, and suitable shades in institutional greenery. They seem to regard safety, aesthetics, and naturalness as priorities in parks. Regarding activities and needs, elderly people prefer Do-It-Yourself (DIY) gardening (such as planting trees, flowers, or shrubs in their yards or allotments) because it enables them to use their imagination to build living environments, and to develop creativity, identity, and freedom. Elderly people prefer to sit and use exercise facilities, not only for leisure, but also for the opportunity to linger in green spaces.

2.5.2 Complexities in understanding preferences

2.5.2.1 Different preferences for a landscape characteristic

Elderly people show different opinions on landscape characteristics, some even contradictory to others. These divided opinions include both the different tastes for features and settings, and the different relative importance of many landscape characteristics. These differences may derive from study methodologies and focuses, or they may reflect complex human-nature interactions. Different preferences may depend on cultural contexts, including but not limited to beliefs, values, public security, social-economic status, health conditions, and household situations (Kaczynski et al., 2014, 2011; Payne et al., 2002; Tinsley et al., 2002). The following sections included some examples.

Inclusive parks versus elderly-specific parks. While a study on urban woodlands found that elderly people seem to fear being the victim of vandalism and other criminal behaviors, like mugging and robbery, perpetrated by young people (Jorgensen & Anthopoulou, 2007), other studies claimed that the elderly prefer to visit inclusive parks or neighborhood open spaces so that watching children playing (Kemperman and Timmermans, 2006; Sugiyama et al., 2008). The difference in opinions also manifested in a study in Los Angeles, where Loukaitou-Sideris et al. (2016) found that low-income elderly people hold different views on inclusive or exclusive parks, but they also emphasized that most participants in their study prefer an elderly-only park. The key concern behind this issue may be security. If a green space has proper supervision and clear visibility, the benefits of access-for-all could serve more people. The importance of security is in line with previous research that a park with good maintenance may promote social contacts by diminishing crimes (Kemperman and Timmermans, 2014; Matsuoka and Kaplan, 2008). This finding also reminds planners that playgrounds for children play a role in encouraging the elderly to visit a park. When playgrounds are under proper monitoring, both children and their grandparents may feel safe and enjoy nature-based recreation.

Diverse land uses versus single land uses. Studies in medium-sized Canadian cities found that the elderly's physical activity levels were promoted in green spaces when parks had more facilities but low land-use diversity (Kaczynski et al., 2010). Nevertheless, another study in Porto, Portugal, argued that the elderly's physical

activity could be promoted by diverse land uses; this could be done by providing more destinations for a walk, such as shops, cultural centers, and places of worship (Ribeiro et al., 2015). The difference reveals that diverse land uses could get people to go out but not necessarily to green spaces. As Kaczynski et al. (2010) claimed, mixed land-use may be associated with more business and busier crossings. That may encourage the elderly to walk for shopping, but not to have nature-based recreation. When it comes to where elderly people spend their leisure time, green spaces appear to compete with other non-residential destinations. Elderly people walk out of the door due to many reasons. They may visit groceries, markets, coffee shops or teahouses, and churches or temples. These destinations may share elderly people's leisure time that could have been spent in green spaces. From another perspective, various destinations may help encourage people to get out. Elderly people can drop by green spaces on their way to different destinations. However, we need more studies to clarify what kind of mixed land use could provide elderly people with both convenience and natural benefits.

High connectivity versus low connectivity. Since people's requirements for an environment often depend on their purposes in using it, elderly people may have different preferences for connectivity when walking for transportation versus walking for recreation (Cerin, Macfarlane, et al., 2013). A study in Hong Kong reported that the local elderly's recreational walking was positively associated with connectivity, and it explained that a great number of intersections was convenient for them to reach any destination (Cerin, Macfarlane, et al., 2013). However, a study in Atlanta claimed that high connectivity might discourage the elderly's walking by interrupting the continuous sidewalks with intersections (Joseph & Zimring, 2007). This issue may depend on whether elderly people consider sidewalks merely as passages to other places, or as recreational places. The former conception emphasizes connectivity and convenience; the latter emphasizes comfort and aesthetics. The difference affects their walking behaviors, choice of path, and preferences for landscape characteristics along roads.

2.5.2.2 Relative importance levels of preferences

Different studies reported different relative importance levels. For example, Kaczynski et al. (2008) claimed that elderly people's physical activity could be significantly predicted by park features and facilities, but it could not be predicted by park size and distance from parks to home. However, other studies argued that a green space within

walking distance could facilitate physical activity (Barbosa et al., 2007; Eronen et al., 2014; Ward Thompson & Aspinall, 2011). Similarly, many studies claimed that the physical settings of an environment played a role in attracting the elderly to parks, but Cohen et al. (2009) argued that opportunities for social contacts may have been more attractive for the elderly than physical settings. Therefore, different relative importance levels reveal that the elderly often altered the order of their preferences in different contexts. Instead of assuming absolute preferences for all, planners should be aware that elderly people in different contexts are sensitive to different landscape characteristics. Planners should find a way to incorporate elderly users' opinions to reduce the uncertainty in design decisions.

2.5.2.3 Preferences of the elderly in comparison to younger groups

Some studies investigated not only elderly people but also young adults and children, and this enabled the comparison of the elderly's preferences with other age groups. We summarized these studies and found that elderly people pay more attention to environmental barriers and dangers, because they worry about accessibility, mobility, and safety (see Figure 2-6). This concern reflects expectations that elderly people are sensitive to adjusting their nature-based recreation due to the decline in their physical abilities. Some studies found that elderly people visit parks less frequently or have less interest in woodland or park facilities than young adults do (Cohen et al., 2009; Payne, Zimmermann, Mowen, Orsega-Smith, & Godbey, 2013; Vecchiato & Tempesta, 2013). The reluctance to visit parks could be explained by a previous US study which indicated that elderly people's desires for nature decreased as they aged (Lyons, 1983). However, it is still questionable whether the elderly's decrease in park visitation reflects a decreased desire to be in nature or is a consequence of their impaired mobility. Thus, in addition to physical activity, more studies need to investigate how elderly people understand and interact with nature, for example, their emotional ties to and local cultural activities in nature.

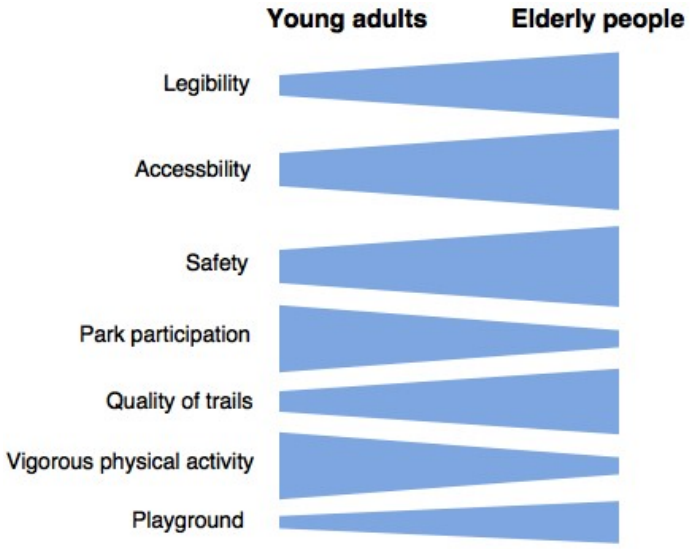


Figure 2-6 The preferences of elderly people in comparison to younger groups (Based on Cohen et al., 2009; Jorgensen and Anthopoulou, 2007; Joseph and Zimring, 2007; Kemperman and Timmermans, 2006; Payne et al., 2013; Pettebone et al., 2011; Yilmaz et al., 2011.). In comparison with young adults, elderly people seem to be more concerned with landscape characteristics like legibility, accessibility, safety, or quality of trails. They also show less interest in park participation or vigorous physical activity.

2.5.3 Limitations of this study

The main limitation of our review is the scope and coverage of included studies. For example, most studies are from English-speaking countries, and only a few studies are from countries experiencing rapid population aging, such as Germany and Scandinavian countries. Moreover, our review lacks comparative studies. Possible reasons for the limitation are as follows. Firstly, relevant papers are not in the databases of Scopus and Web of Science or cannot be searched by our English search terms. Secondly, relevant studies are in book chapters, reports, and websites rather than in peer-reviewed journals. Thirdly, few quantitative comparative studies have yet been published.

2.6 Conclusions and implications

Landscape planners can better fulfill the elderly's needs for nature-based recreation by learning about their preferences. This review reveals the state of knowledge of the elderly's preferences: where and how they have nature-based recreation, what basic needs they want to be fulfilled, and what landscape characteristics they prefer. We

found existing studies primarily on walking and general physical activity in urban parks. Moreover, despite contextual differences, the elderly show common preferences, which can be classified as accessibility, infrastructure and facility, maintenance, and landscape features that are aesthetic, diverse, and comprehensible. Meanwhile, interactions between people and nature play a role in moderating the relative importance levels of landscape characteristics. These findings can help landscape planners to better address the elderly's needs and improve their wellbeing.

Based on the review, we suggest further studies on the following aspects:

1. More studies need to discover elderly people's emotional ties with green spaces, for example, their discovery, creativity, identity, freedom, or any local cultural activities in green spaces. Previous studies focused on functional attributes, like how a landscape determines elderly people's walking or physical activity. Understanding of the elderly's rich emotional and cultural attachment to green spaces is still vague.
2. More studies need to describe elderly people's preferences quantitatively for comparative research. Many existing studies used presence/absence or more/less to describe preferences; those classifications are too crude to permit valid comparison of preferences across contexts and are certainly not precise enough to guide practitioners.
3. More studies need to investigate the urban/rural difference in elderly people's preferences for nature-based recreation. Since most existing studies focused on urban areas where streetscapes or urban parks are dominant, we need to know more about preferences of elderly people living in rural areas. Rural areas may have different prominent land covers (cropland, forest, or wetland), different public service provisions (public transportation, security), and distinctive local cultures (festival celebration, inherited tradition, and social organization). Planners need to consider the potential difference between urban and rural contexts.

There are three main implications for planning practitioners. Firstly, it is recommended in most practices to consider our core findings of preferences, such as aesthetics, accessibility, and well-equipped recreational and supporting facilities. Since elderly people have some common preferences for landscape characteristics, core findings of

preferences may help to identify the most effective design factors. Secondly, practitioners should prioritize preferences based on how elderly people want to interact with nature. In neighborhood greenery, elderly people are sensitive to connectivity, air quality, noise, and business settings. In institutional greenery, they are sensitive to season-changing landscape, open views, and suitable shades. In parks, they are sensitive to safety, naturalness and aesthetics. When engaging in different activities, people also have different expectations and requirements for landscape characteristics. Planners need to learn the opinions of local elderly people. Thirdly, practitioners are encouraged to provide opportunities for DIY gardening. Apart from physical activity, gardening is effective in developing the elderly's creativity, identity, and participation, which are somehow neglected in many green spaces.

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Conflicts of interest

The authors declare no conflict of interest.

Appendix A.

For the appendix of the paper see the supplementary file.

CHAPTER 3. EXPLORING NATURE-BASED RECREATION OPPORTUNITIES FOR ELDERLY PEOPLE IN URBAN AREAS: A SPATIAL INVESTIGATION IN HANNOVER, GERMANY[2]

Abstract

With elderly people comprising a growing share of the population, landscape planners need to consider the specific requirements of this group of citizens to enhance opportunities for nature-based recreation (NBR). However, few studies have aimed at spatially assessing the recreation potential, demands, and opportunities for elderly people in urban areas. The aim of this paper is to spatially model NBR opportunities for and demands of elderly people in urban areas. Our method is based on an adapted ESTIMAP recreation model and considers special factors and parameters to better reflect elderly people's preferences for NBR at the city scale. It assesses NBR opportunities by considering landscape aesthetics, various types of facilities, and proximity. Street network was used to understand elderly people's walking behaviors related to urban green spaces. A case study in Hannover, Germany demonstrated the applicability of the method and introduced a simple validation. The results show that Hannover has many green spaces, but only parts of them offer high recreation opportunities for elderly people. Some existing parks are lacking diversity in landscape components and coverage of facilities, resulting in a compromise in aesthetics and opportunities. Places with high opportunities are mainly found near the lake in the southern city and in the urban forests near the northeast. The high demands are mainly found in a strip of residential areas across the city center, but the distance between them and places of high opportunities are often beyond walking distance. Our results provide planning implications based on different assessment results.

Keywords: Elderly people; Nature-based recreation; Population aging; Landscape architecture; mapping; Design.

[2] This chapter was based on manuscripts submitted to a peer-reviewed journal as Wen, C., Albert, C., Von Haaren, C. Exploring nature-based recreation opportunities for elderly people in urban areas: A spatial investigation in Hannover, Germany

3.1 Introduction

Recent demographic trends in population aging have received increasing attention from landscape and urban planning, which need to develop elderly-friendly environments (Alidoust & Bosman, 2015; Wen, Albert, & Von Haaren, 2018). The term "elderly people" often refers to the population above the age of 60 or 65 according to the census in many countries; the term is also related to retirement and decline in functional capability (Milanović et al., 2013; Orimo et al., 2006). For improving their quality of life and wellbeing, planners need to consider elderly people's needs for nature-based recreation (NBR) (Dzhambov & Dimitrova, 2014; Finlay et al., 2015; La Rosa, Takatori, Shimizu, & Privitera, 2018; Wen et al., 2018). When having leisure activities in nature, such as walking, relaxing, and playing in green spaces, elderly people can gain multiple health benefits including physical fitness, social integration, and stress reduction (Abraham, Sommerhalder, & Abel, 2010; Hung & Crompton, 2006; Leaver & Wiseman, 2016; Lee & Maheswaran, 2011; Phillips et al., 2011). NBR plays a role in developing elderly-friendly environment (La Rosa et al., 2018; World Health Organization, 2007).

Mapping NBR attracts growing interest in landscape planning because it helps plan-makers better understand different environmental conditions for NBR in a spatially explicit way (Casado-Arzuaga et al., 2013; Cortinovis & Geneletti, 2018; Maes et al., 2015). Regarding NBR as one type of cultural ecosystem services that people obtain from nature with the help of infrastructures (Burkhard, Kandziora, Hou, & Müller, 2014; Costanza, 2008; Milcu, Hanspach, Abson, & Fischer, 2013), recent mapping practices have considered following components in the service delivery:

(1) Recreation potential, which represents the state of nature with emphasis on naturalness, biophysical characteristics, and aesthetics related to the plantation (Hermes et al., 2018; van Zanten et al., 2016);
(2) Human inputs associated with green spaces, for example, infrastructure, roads, and facilities (Cortinovis, Zulian, & Geneletti, 2018; Peña, Casado-Arzuaga, & Onaindia, 2015);
(3) Recreation demands, often indicated by population hotspots, visits, or a proxy of uses (see the review by Wolff, Schulp, & Verburg, 2015);

(4) Recreation opportunities, for example, classifying recreational conditions based on the recreation potential and human inputs using the ESTIMAP model (Baró et al., 2016; Paracchini et al., 2014; Vallecillo et al., 2019), and presenting multiple criteria using a tiered approach (Grêt-Regamey et al., 2015).

Mapping NBR in the urban environment is of particular interest because in many countries the urban population is growing, leading to an increasing demand for NBR in cities (Baró et al., 2016; Rocha, Zulian, Maes, & Thijssen, 2015). Assessing NBR in urban areas need to understand human-nature interactions, for example, how people travel to green spaces, where and how they recreate, and what facilities they use (Lupp et al., 2016). Mapping NBR at the city scale requires sufficient detailed data of local spatial configuration (Malinga, Gordon, Jewitt, & Lindborg, 2015; Rocha et al., 2015).

Only a few studies have investigated the spatial patterns of NBR related to elderly people at the city scale. For some exceptions, a recent study in Trento, Italy has mapped the recreational potential and opportunities for elderly people and youth after adapting a localized ESTIMAP model (Cortinovis & Geneletti, 2018; Cortinovis et al., 2018). The study has considered expert scoring of natural features, land covers, and facilities like bus stops, trails, and playgrounds. In another study with cases in Catania, Italy and Nagoya, Japan, researchers have mapped elderly people and children's accessibility to categorized urban parks (La Rosa et al., 2018). The categorization was based on park size, land cover, tree cover, and presence of some facilities. The results help to identify key locations to improve green space quantity, quality, or accessibility (La Rosa et al., 2018).

However, assessments still need to concern how to better reflect preferences and needs of investigated social groups (Casado-Arzuaga et al., 2013; Haase et al., 2014; Schirpke, Meisch, Marsoner, & Tappeiner, 2018). In this sense, existing studies often applied the same indicators of NBR to study elderly people and other social groups (Cortinovis & Geneletti, 2018; Kabisch & Haase, 2014; La Rosa et al., 2018). While this approach has provided insights in comparing different social groups, elderly people's preferences for NBR can remain unclear. Elderly people might have different priorities in requirements for environmental attributes from younger groups (Loukaitou-Sideris et al., 2016; Wen et al., 2018). They are more likely to prefer urban environment that are naturally diverse (Jorgensen & Anthopoulou, 2007; A.

Kemperman & Timmermans, 2014; Loukaitou-Sideris et al., 2016; Reynolds, 2016; Takemi Sugiyama & Ward Thompson, 2008; Wen et al., 2018), accessible from home (Artmann et al., 2017; Cerin, Macfarlane, et al., 2013; Jorgensen & Anthopoulou, 2007), and well-maintained (Artmann et al., 2017; T. W. Chao et al., 2014). When mapping recreation potential of a place, existing studies usually considered the natural feature or land use of that particular place (pixel) (Baró et al., 2016; Cortinovis et al., 2018; Vallecillo et al., 2019). However, people's visual experience for a place can also depend on its surrounding areas, in which the diversity of landscape components plays a role (Hermes et al., 2018). Especially in urban areas, elderly people often prefer to visit paved squares surrounded by trees (Alves et al., 2008; Hino et al., 2010). These built environments can be overlooked. Moreover, when accounting for the accessibility of natural features and facilities, studies often applied Euclidian distance that measures straight line distance (Baró et al., 2016; Cortinovis et al., 2018; van Riper, Kyle, Sutton, Barnes, & Sherrouse, 2012; Wüstemann, Kalisch, & Kolbe, 2017). Using Euclidian distance is intuitive and generally suitable in many contexts, but the measured distance is likely to be less than the network distance (Zhang, Lu, & Holt, 2011). In urban areas with dense streets, network analysis can capture the traffic path and actual walking distance more accurately (La Rosa, 2014; Zhang et al., 2011). Therefore, it would be more suitable to use network distance to understand elderly people's NBR because they are sensitive to walking distance and barriers (Kaczynski, Potwarka, & Saelens, 2008; Ribeiro, Pires, Carvalho, & Pina, 2015).

The aim of this study is to spatially model NBR opportunities for and demands of elderly people in urban areas. Based on existing evidence of elderly people's preferences for landscape characteristics, we adapted the ESTIMAP recreation model by considering indicators and parameters that reflect elderly people's preferences at the city scale (Cortinovis et al., 2018; Paracchini et al., 2014; Wen et al., 2018; Zulian et al., 2013). This study used Hannover, Germany as a case to analyze recreation potential, opportunities, demands. Hannover is undergoing a process of population aging and has initialized a plan to develop green spaces to improve citizens' wellbeing (Landeshauptstadt Hannover, 2016, 2017a). The results can help to provide planning suggestions to develop an elderly-friendly city regarding NBR.

The main research questions are:

- What recreation potentials, opportunities, and demands of elderly people for NBR exist in the Hannover urban area?
- How are elderly people's demands for NBR met or unmet given the current urban structure?

3.2 Study design

3.2.1 General framework

This study adapted the ESTIMAP recreation model, which is flexible and extensible to assess local urban environments (Paracchini et al., 2014; Zulian et al., 2013). The model has been successfully adapted for different applications and research focuses (Carvalho et al., 2017; Cortinovis et al., 2018; Vallecillo et al., 2019). It accounts for the recreation opportunities by cross-tabulating different classified thematic maps or overlaying them. Key thematic maps of the model usually include the recreation potential map, proximity map, and demand map (Baró et al., 2016; Paracchini et al., 2014; Zulian et al., 2013). Each thematic map can be composed of different indicators that reflect particular research interest (Carvalho et al., 2017).

Table 3-1 Protocol of adapting the ESTIMAP recreation model for this study

Step	Key questions	Consideration
Type of knowledge production	What is the application of the final map?	The final maps of assessment can inform local planners of different conditions of NBR at the city scale. The spatially-explicit information can help to identify key locations for developing urban green spaces.
	How is the involvement of stakeholders	Designing the model considers literature, demographic reports, and local plans related to elderly people.
Spatial and temporal scale	What temporal and spatial scales are considered?	The model concerns biophysical conditions of nature and human inputs at the city scale. The model is expected to be relevant at present or in the near future.
Model rules	What components should be included?	Based on evidence of elderly people's preferences for NBR (Loukaitou-Sideris et al., 2016; Wen et al., 2018), the components should reflect environmental features that affect different aspects of preferences. Spatial indicators for features are

		developed based on 1) whether they can represent elderly people's NBR in urban areas, 2) whether data are available at the city scale.
	How can we combine these components?	The model needs concern both overlay approach and "advanced lookup table" approach (Paracchini et al., 2014). The former helps to study related features by combining them into one category, while the later helps to study two different categories of features by cross-tabulation.
Get feedback	Are there any verifying maps from independent data?	So far in the study area, there is no assessment of recreation opportunities for elderly people to validate our mapping results. To do a simple comparison, we introduced a map based on the "Ecosystem services matrix approach." Future work is possible to calibrate and verify the model through field surveys.

Note: the protocol is referenced to Carvalho et al., 2017.

This study has developed a localized application to address elderly people following a recommended protocol (Table 3-1) of adapting the ESTIMAP model (Carvalho et al., 2017). The protocol identifies key factors in the adaption process including map production, spatial and temporal scale, and model rules. This study has proposed a framework of factors to assess NBR potential, opportunities, and demands (Figure 3-1). The selection of factors has taken into account the existing evidence of elderly people's preferences for landscape characteristics (Table 3-2) (Alves et al., 2008; Aspinall et al., 2010; Loukaitou-Sideris et al., 2016; Wen et al., 2018). When operationalizing factors into spatial indicators, we considered what data is available to represent local contexts at the city scale (de Groot, Alkemade, Braat, Hein, & Willemen, 2010).

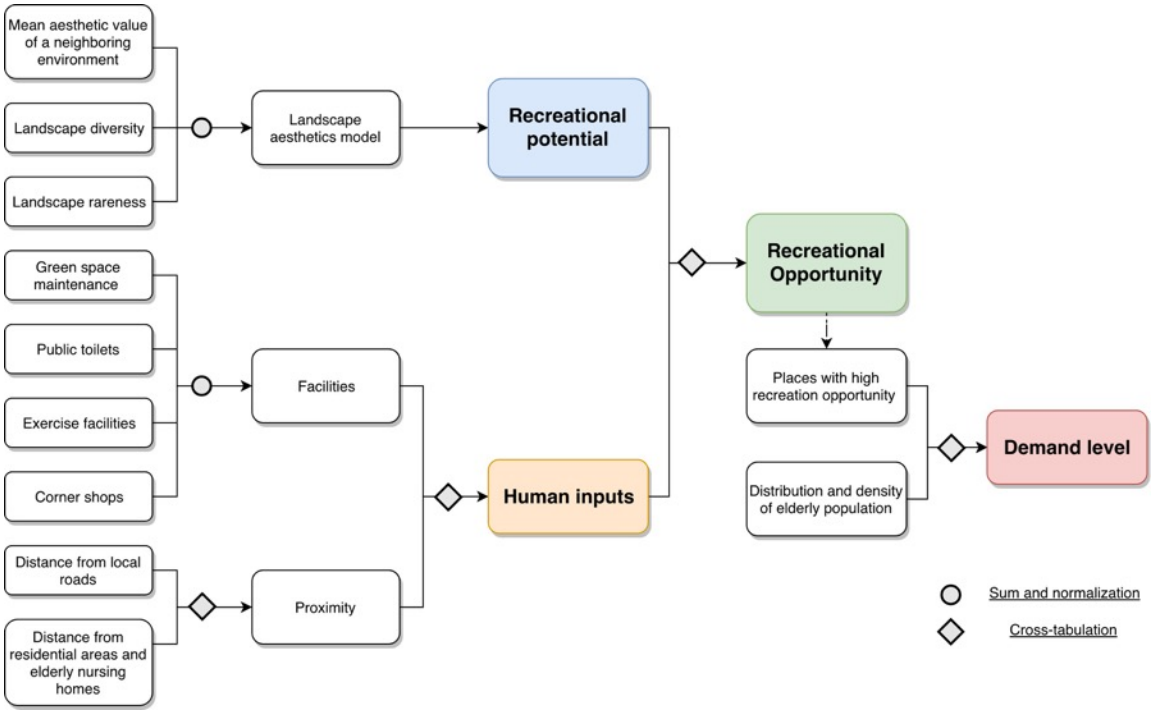

Figure 3-1 Flowchart of assessing recreation potential, opportunities, and demands for elderly people.

Table 3-2 Component, configuration, and data to study the recreation opportunities

Component	Relevant question	Model configuration				
		Model used	Layer(s)	Number of layers	GIS Data	Specific adaptation for elderly people
Recreation potential	How is the quality of landscape aesthetics distributed?	Landscape aesthetics quality model	Average landscape aesthetic value in a surrounding environment: a value calculated by focal statistics for each cell, indicating the average aesthetic value from the cell's surrounding areas. Landscape diversity value: a Shannon Diversity Index was applied. Landscape rareness value: an index to indicate whether the biotope of a place belongs to any rare types in the study area.	3	BRH	The landscape aesthetics quality model is adapted from a recent study in German contexts (Hermes et al., 2018). For better understanding elderly people's visual experience in urban areas, we have used local fine-scaled biotope dataset and adjusted the extent that decides the surrounding environment to 100m.
Human inputs	How are the supporting facilities available in different locations of the city?	Facilities	Green space maintenance: an index of whether the biotope of a place belongs to leisure and sports fields, historical sites, or graveyards. It assumes these types of green spaces get frequent maintenance and therefore are suitable for NBR. Public toilets: service areas of public toilets classified by network distances. Exercise facilities: service areas of exercise facilities classified by network distances. Corner shops: service areas of corner shops classified by network distances.	4	DLM, HGW, OSM, KIOD	Based on existing evidence of elderly people's preferences for NBR, the environmental features are selected. The affected areas of these facilities are adjusted by distances that reflect elderly people's walking for leisure in urban settings.

	How accessible are the areas from residential areas, nursing homes, and roads?	Proximity	Proximity of local roads. Proximity of residential areas and nursing homes.	2	HGW OSM	Detailed local roads, residential building, and nursing homes are added to the model.

BRH: Biotopes in Region Hannover 2017, from the Minister for the Environment, Energy, Construction and Climate Protection, Lower Saxony.

DLM: Digital landscape model in Region Hannover (ATKIS Basis DLM), from the State Office for Geoinformation and Land Surveying, Lower Saxony.

OSM: Street Network from OpenStreetMap, processed by the Python package OSMnx (Boeing, 2017).

HGW: Digitalized based on the open data inventory or maps from the official website of the City of Hannover (https://www.hannover.de).

AADT: Annual average daily traffic (in German: DTV data), from the City of Hannover.

KIOD: Geocoded from kiosk business open inventory data (source: kioskguide.de), supplemented by information from google map

3.2.2 Assessing NBR potential

This study assessed and mapped NBR potential by adapting a recent landscape aesthetic quality (LAQ) model in the context of Germany (Hermes et al., 2018). Landscape aesthetics, as people's visual preferences for nature, depends on different landscape properties, such as naturalness, diversity, rareness, and coherence (Hermes et al., 2018; Jankevica, 2013; S. Kaplan, 1987; Thélin & Roth, 2010; van Zanten et al., 2016). Landscape aesthetics often plays a dominant role in affecting elderly people's NBR, and compared to the general population, the elderly might have a stronger preference for diverse plants, predictable environments, and distinctive features (Alves et al., 2008; Aspinall et al., 2010; Hung & Crompton, 2006; Jorgensen & Anthopoulou, 2007; Mitchell et al., 2004; Wen et al., 2018). The original LAQ model applies a multi-layered approach to study the aesthetic quality at the national scale (Hermes et al., 2018). This study adjusted factors and parameters of the model to study elderly people at the city scale. Three factors were included:

(1) Average landscape aesthetic value in a surrounding environment. We applied a raster-based "moving window" approach to calculate the average aesthetic value of a grid cell considering its surrounding areas. This study adjusted the extent of surrounding areas from 1 km in the original model (Hermes et al., 2018) to 100m, aiming at reflecting elderly people's visual experience in the urban areas. Before the calculation, the aesthetic score for each type of landscape components was prepared based on existing studies in local contexts or in Germany (Boll, Kempa, Von Haaren, & Weller, 2014; Boll, Von Haaren, & Von Ruschkowski, 2014; Haaren & Hülsbergen, 2008; Nohl, 2001). It should be noted that the source of the referenced aesthetic value is not only from elderly respondents but also from other age groups (see Boll, et al., 2014; Nohl, 2001). That might be a potential limitation for this study. However, so far there is no field survey specifically on scoring elderly people's landscape aesthetics in the study area.

(2) Landscape diversity value: this is calculated by the Shannon Diversity Index (SHDI). The value depends on the number of distinct landscape types as well as evenness in a surrounding environment similar to last step (Frank, Fürst, Koschke, Witt, & Makeschin, 2013; Nagendra, 2002). In this context, a high value indicates a more diverse environment in which landscape types are equality abundant. The formula is defined as:

$$SHDI = -\sum_{i=1}^{m} P_i * \ln P_i$$

In this formula, m is the number of landscape component types in the given area; P_i is the area proportion of type I in the given area.

(3) Landscape rareness value: this indicates whether a particular biotope is rare in the study area. This study applied an approach similar to previous studies that measured rareness using a threshold of area proportion (Hermes et al., 2018). This study defines the rareness as whether a type of landscape component belongs to one of the rarest types, whose combined areas cover 5% of the total study area. The approach reflects the findings that elderly people prefer distinct features in the urban environment (Mitchell et al., 2004). The influence of those rare areas was set based on a distance decay effect function (Zulian et al., 2013):

$$f(d) = \frac{1 + \mathrm{K}}{K + e^{a*d}}$$

The influence of rare areas f(d) is a function of distance d; *K* and *a* are both constant parameters that control the distance decay effect. In this study, *K* is calibrated to 208.603 and *a* to 0.0535 so that the limit of influential distance is 200m, and its influence is reduced by half at the middle distance.

For the final scoring of landscape aesthetics, the three factors above are summed and normalized between 0 (worst aesthetics) – 1 (best aesthetics), using the same approach in ESTIMAP (Paracchini et al., 2014; Zulian et al., 2013).

3.2.3 Assessing human inputs

"Human inputs" refer to necessary facilities and infrastructure that help people to reach and enjoy the benefits provided by nature (Albert et al., 2016; Burkhard et al., 2014). This study categorized human inputs for NBR as facility-related or proximity-related inputs.

Facility-related inputs consist of four factors – green space maintenance, toilets, exercise facilities, and corner shops. These factors reflect environmental features that play roles in elderly people's NBR (Loukaitou-Sideris et al., 2016; Wen et al., 2018).

Elderly people like green spaces near toilets, small business settings (e.g. corner shops or kiosks), and historical sites (e.g. churches or graveyards) (Alves et al., 2008; Aspinall et al., 2010; Jorgensen & Anthopoulou, 2007; Ribeiro et al., 2015). Elderly people expect green spaces to be regularly-maintained for safety consideration (A. Kemperman & Timmermans, 2014; Takemi Sugiyama & Ward Thompson, 2008). They enjoy recreational facilities like exercise equipment and leisure fields for physical activity (Chow, 2013; Eronen et al., 2014).

The impact of facilities was measured by network distance. In urban areas with dense streets, network distance can capture the traffic path and actual walking distance accurately (La Rosa, 2014; Zhang et al., 2011). To set the distance threshold, this research referenced recommended walking distance for short-trip leisure and elderly people's walking behavior (Grunewald, Richter, Meinel, Herold, & Syrbe, 2017; Kaczynski et al., 2008). We set the maximal walking distance for facilities to 500m and assume that facilities can benefit their surrounding areas with a distance-decay effect until 500m at the furthest.

Proximity-related inputs consist of two factors, proximity to local roads and to residential buildings or nursing homes. The distances to each factor are respectively measured and classified, and then the proximity rating was cross-tabulated by the two distance maps. This approach of identifying accessible areas is similar to a recent study in urban settings (Vallecillo et al., 2019), but for understanding elderly people, this study lowered distance thresholds to 500m for residential buildings and 200m for local roads. Thus, a score of human inputs was acquired using a cross-tabulation of the proximity-related inputs and the facility-related inputs. A high value for human inputs indicates that the place is both accessible and convenient.

3.2.4 Assessing NBR opportunities and demands

We acquired NBR opportunities using a cross-tabulation of NBR potential and human inputs. The areas with a high value of NBR opportunities are considered suitable for elderly people's NBR as they are aesthetic, accessible, and convenient. Those areas with the highest NBR opportunities were selected to further analyze NBR demands.

This study calculated the detailed distribution of elderly people based on population grids at the 100m scale and the demographic statistics for each block census. Each grid

was used to calculate the distance to the nearest place of the highest recreation opportunities. Then the classified distance was cross-tabulated by different levels of elderly population density to result in the demand level (Baró et al., 2016; Zulian et al., 2013).

Last, for validating the recreation opportunities of this study, we applied an "ecosystem services matrix approach" (Burkhard et al., 2014) to compare the spatial patterns of hotspots (high-value places). The matrix approach is a well-established method for assessing and mapping various ecosystem services. It represents a strongly simplified approach to assessing ecosystem services (cf. tier 1 approach in Grêt-Regamey et al., 2015) by scoring different types of land use based on expert knowledge. The scoring can be applied to some standardized map data, for example, CORINE and Urban Atlas from the European Environmental Agency (Burkhard, Crossman, Nedkov, Petz, & Alkemade, 2013; Burkhard et al., 2014). Although the matrix approach recreation model is not specifically for elderly people in the study site, it can help to understand and compare general spatial patterns of NBR at the city scale.

3.2.5 Study area

This study considered Hannover, Germany as the study area. Hannover has a population of 541,000 with an average age of 42.4 years (Landeshauptstadt Hannover, 2017b). The proportion of elderly people over 65 in Hannover was 18.8%, slightly lower than the national average (Landeshauptstadt Hannover, 2017b). Figure 3-2 shows the distribution of the elderly population in Hannover. By 2030, the average age of citizens can increase to 44.3, with 21.9% of the population over 65 (Region Hannover, 2016). Hannover represents some big cities in Germany that are undergoing population aging, and the case study is an attempt to inform decision-making regarding NBR in the city with similar demographic characteristics (Statistisches Bundesamt, 2016).

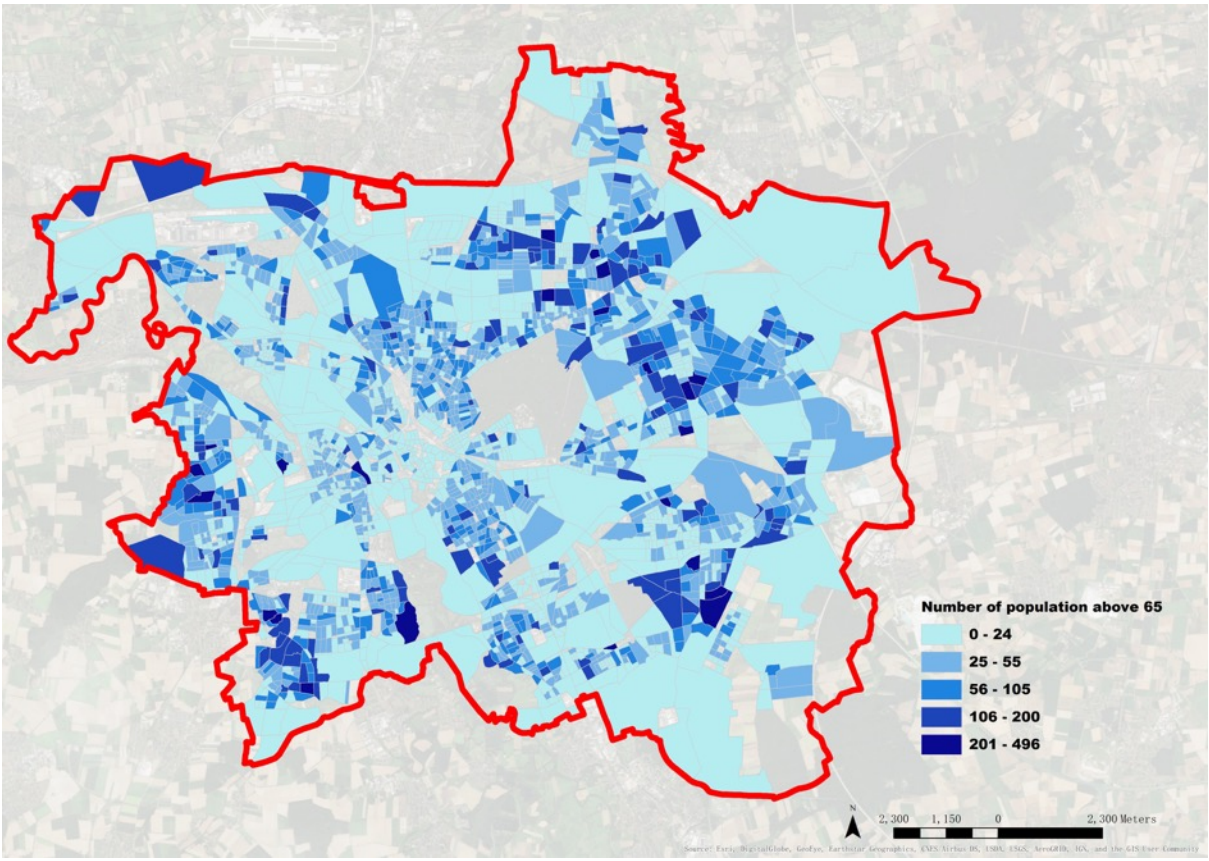

Figure 3-2 Distribution of elderly people in Hannover (source: The City of Hannover). It shows a spatial pattern that many communities with a high number of elderly people are on the outskirts of the city.

Hannover is famous for the exhibition industry, livable environments with large green spaces, and a “less stressful lifestyle” (see the news report by O’Hare, 2017). The city covers an area of 204 km^2. The percentage of built areas including residential, commercial, and industrial areas is 53.7% (see Figure 3-3). Forests comprise 11.7%, rivers and lakes 2.6%, and the wetlands, moors, and other green spaces combine for 7%.

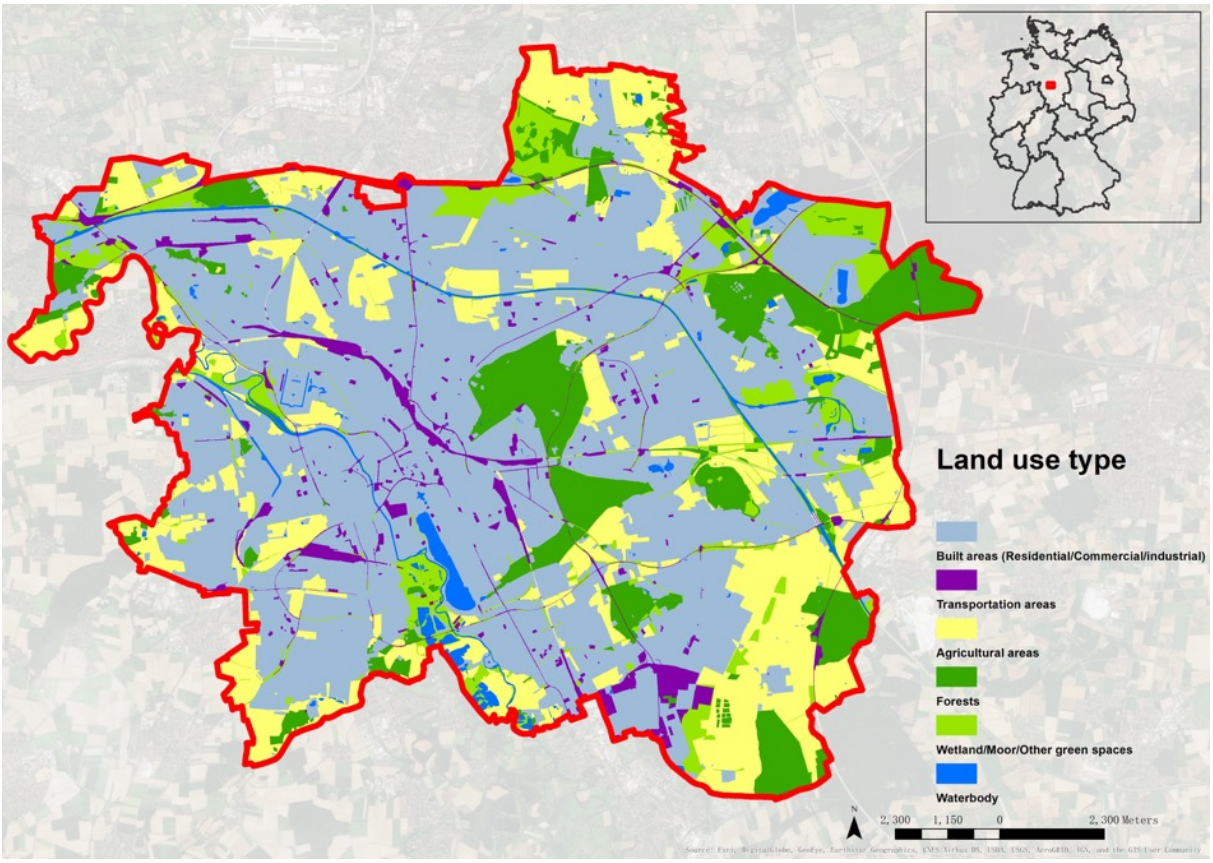

Figure 3-3 Land use of Hannover city (source: DLM Region Hannover). Existing green spaces mainly include a few medium-sized urban parks near the city center as well as urban forests near the east boundary.

3.3 Results

3.3.1 Spatial patterns of recreation potential and human inputs

The landscape aesthetic quality model shows an uneven distribution of recreation potential in Hannover (Figure 3-4, left). While built areas that cover more than half of the city offer low recreation potential, we found that areas with high potential are near the boundaries. These areas include wetlands and lakes in the south, royal gardens in the west, and urban forests in the northeast. By contrast, areas with low recreation potential are the densely-populated districts near the city center and the agricultural land. Notably, not all existing green spaces are found with a high potential. Two large urban parks near the city center are often called the “green heart” of the city, but only small parts of them show a high potential.

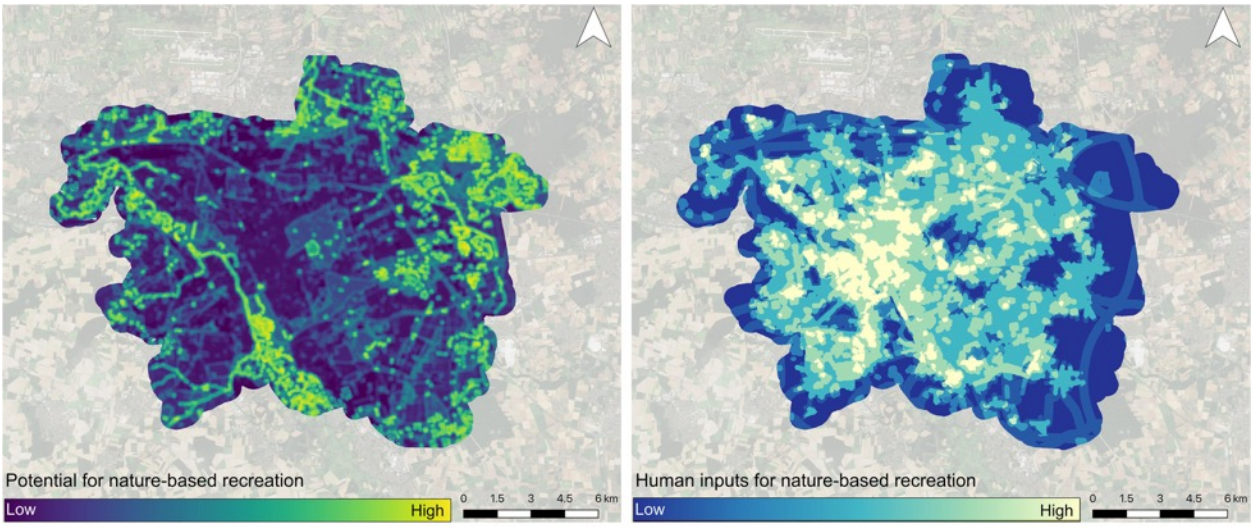

Figure 3-4 NBR Potential for elderly people (left), and NBR human inputs for elderly people (right). The NBR potential value is normalized to 0–1 range in which 0 indicates the lowest potential and 1 the highest potential. The human input value is ranked based on cross-tabulation of facility-related inputs and proximity-related inputs, and the figure shows the range from the lowest human inputs (dark) to the highest (light).

In contrast to recreation potential, the assessment of human inputs shows that areas with the best human inputs are around the city center and spreading several kilometers outside (Figure 3-4, right). Moreover, the west of the city is more densely covered by facilities than the eastern part. Although areas near the eastern boundary are found with high recreation potential, few investigated facilities are present there.

3.3.2 Summary of NBR opportunities and demands

Figure 3-5 shows spatial patterns of NBR opportunities for elderly people in Hannover. Places with high opportunities meet the two requirements at the same time, being aesthetic and with good human inputs. The results identified two key linear patterns with high recreation opportunities (Figure 3-5). They are either along the lakesides or as urban greenway corridors. A few small areas with high recreation opportunities are scattered throughout the city. They might indicate street gardens that are suitable for elderly people's NBR.

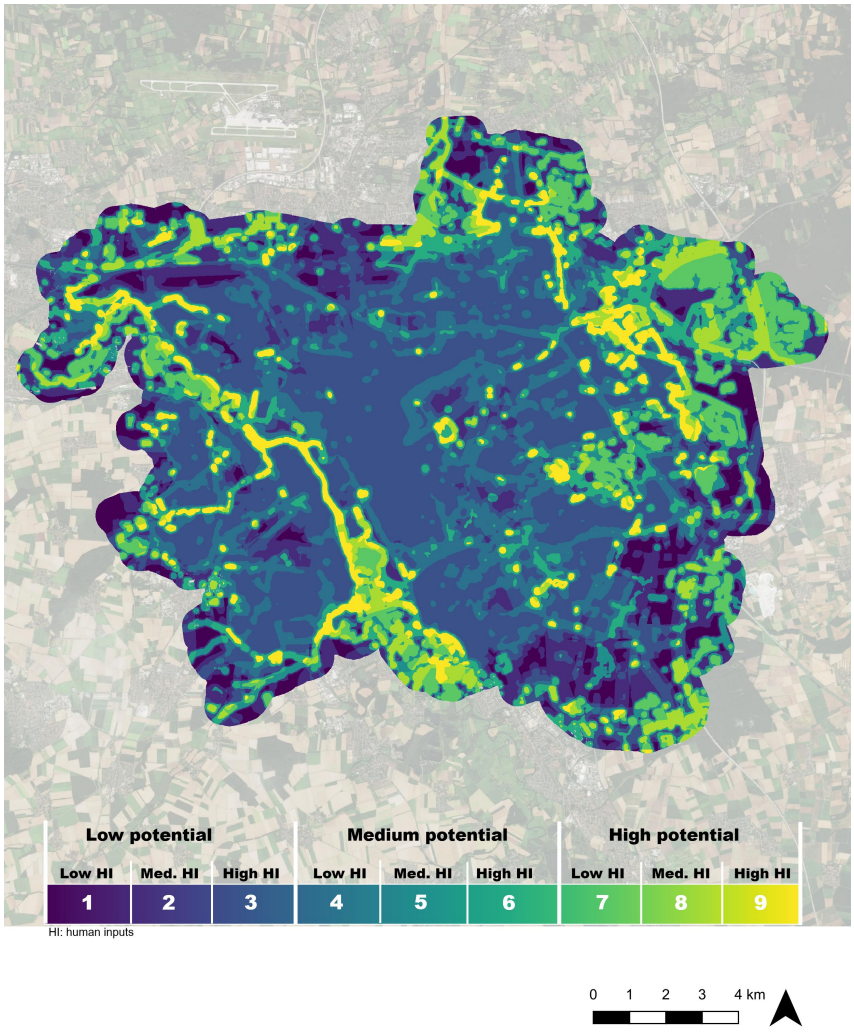

Figure 3-5 NBR opportunities for elderly people. The value is ranked to 9 classes based on cross-tabulation of NBR potential and human inputs. The figure shows the range from the lowest opportunities (dark) to the highest (light).

Table 3-3 Zonal statistics of mapping results for Hannover

Code	District	Total Population (inh.)	Percentage of people above 65 (%)	Average aesthetics (0-1 scale)	Average recreation opportunities (1-9 scale)	Areas of the highest opportunities value (km^2)
1	Mitte	37254	14.2	0.24	3.9	10.7
2	Vahrenwald-List	70720	16.6	0.12	3.3	8.2
3	Bothfeld-Vahrenheide	49667	22.4	0.36	4.6	30.7
4	Buchholz-Kleefeld	45241	22.6	0.23	3.9	14.0
5	Misburg-Anderten	33545	21.8	0.46	5.1	28.2
6	Kirchrode-Bemerode-Wülferode	32069	21.4	0.25	3.9	23.8
7	Südstadt-Bult	43119	16.8	0.28	3.6	7.1
8	Döhren-Wülfel	34512	20.8	0.33	4.2	16.5
9	Ricklingen	46048	21.6	0.21	4.3	14.7
10	Linden-Limmer	45725	12.2	0.30	4.1	8.2
11	Ahlem-Badenstedt-Davenstedt	34467	22.3	0.19	4.3	9.9
12	Herrenhausen-Stöcken	36859	19.1	0.28	4.4	12.2
13	Nord	32435	13.3	0.30	3.7	10.9
	Hannover city	541661	18.7	0.32	4.3	204

Note: the highest opportunities indicate the value 9 in the opportunity map; the source of population is from the City of Hannover in 2018.

Table 3-3 summarizes the average value of recreation opportunities for the whole city and for each district. The average value of recreation opportunities of the whole city is 4.3 in the 1-9 scale. From the table, we can identify districts that have a large share of elderly people (>20%) but whose value of recreation opportunities is below the average. These districts include Buchholz-Kleefeld and Kirchrode-Bemerode-Wülferode.

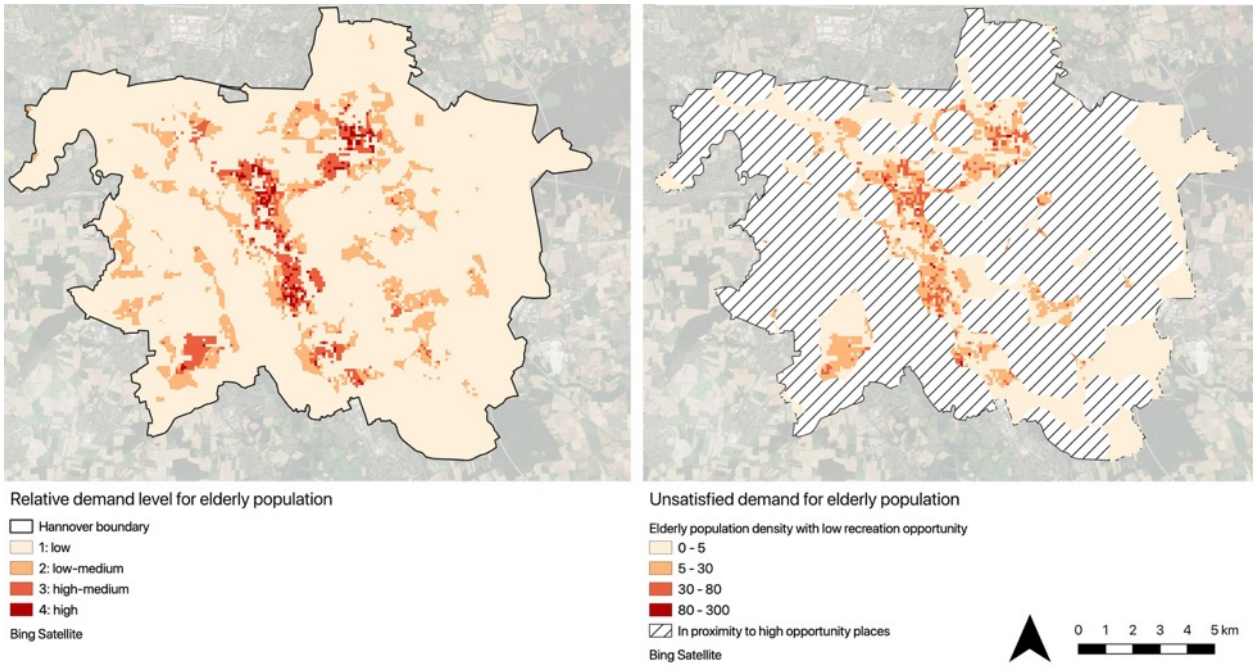

Figure 3-6 NBR demand level for elderly people (left) and unsatisfied demands for the elderly population (right). The value of demand level is based on cross-tabulation of elderly population density and the distance to nearest high recreation opportunity places (explained in Table 3-4). The unsatisfied demands indicate the density of the elderly in areas that are beyond walking distance (600m) to the nearest places with the highest recreational opportunities.

Table 3-4 The demand level of elderly people's NBR

		Distance to the nearest high recreation opportunity places (m)			
		0 ~ 300	300 ~ 600	600 ~ 900	900 ~ above
Elderly population density (elderly pop. /ha)	0 ~ 5	1	1	1	1
	5 ~ 30	1	2	2	3
	30 ~ 80	1	2	3	4
	80 ~ 300	1	3	4	4

The approach is referenced to Baró et al., 2016; Paracchini et al., 2014.

The distribution of demand is summarized in Figure 3-6, considering the density of elderly people in each population grid and its distance to the nearest high opportunity places (for cross-tabulation see Table 3-4). Areas with the highest demand are mainly in a strip of land across the city center. These areas are densely populated by elderly people and are often beyond a walking distance of 600m to high opportunity places.

3.3.3 A validation of the recreation opportunities

This study introduced a simple validation based on the ecosystem service matrix approach (Burkhard et al., 2014). After applying the hotspot analysis (Getis-Ord Gi statistics in ArcGIS), the distribution of z-score was respectively calculated from the maps of recreation opportunities and of the matrix approach (Figure 3-7). We find that the spatial patterns of cold and hot spots generally match between two maps in the outer-city area. Both models have captured the hot spots near lake areas as well as the cold spots near the southeastern boundaries. However, we also find that our proposed method provides a more detailed analysis of green space values for recreation of the elderly by taking into account the issues of access and infrastructure, resulting in much lower NBR values in the inner-city area. Note that two models are based on different input data, methodologies, and focuses. Therefore, the comparison here is more for a visual inspection of spatial patterns of NBR regarding hot spots and cold spots.

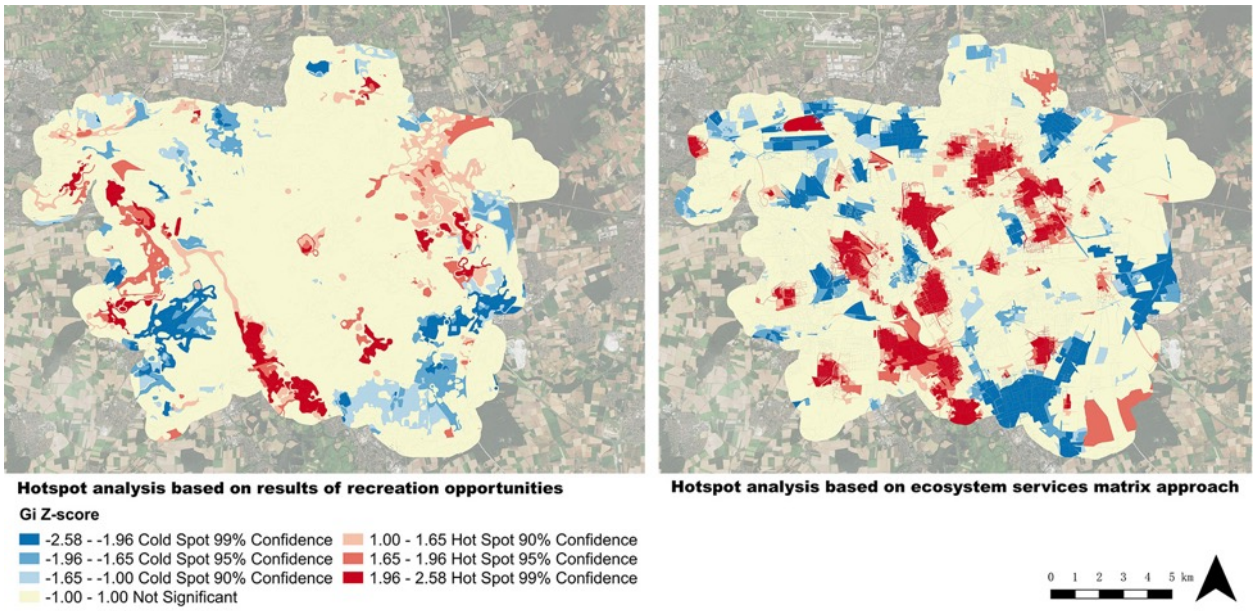

Figure 3-7 Hotspot analysis based on the results of recreation opportunities for elderly people (left), and hotspot analysis based on the ecosystem service matrix model (right) using Urban Atlas data from the European Environment Agency. The calculated z-score indicates how many standard deviations the value differs from the mean.

3.4 Discussion

3.4.1 Recognition of elderly people's preferences in assessing NBR

To answer research questions of how NBR is spatially distributed for elderly people, this study built a model to understand their preferences and needs in urban contexts by adapting the ESTIMAP recreation model. Considering landscape aesthetics, various facilities, and proximity, the results demonstrate spatial distributions of recreation potential, opportunities, and demands at the city scale. For the case study in Hannover, only parts of existing green spaces are found with high recreation opportunities for elderly people. We identified highest NBR opportunities mainly in two linear areas, one along the lake and the other one across the northeast of the city. Most demands are found near the city center where elderly people are densely-populated, but they are often beyond the walking distance to the nearest places with high NBR opportunities.

For guiding green space development, the study has used indicators as a proxy to quantify and map NBR, instead of demonstrating the actual visits of elderly people. The data of detailed visits for short-trip recreation are usually not available (Boll, Von Haaren, et al., 2014), and this is also the case for the vulnerable groups including elderly people. Therefore, this study is an attempt to spatially assess a specific vulnerable group as the stakeholder of green space development. Two recent studies have also used indicators to assess NBR related to elderly groups, although they focus more on accessibility (La Rosa et al., 2018) or planning scenarios for redeveloping brownfields (Cortinovis et al., 2018). Compared to them, this research focuses on elderly people and show similar results that pertinent planning suggestions need base on spatial assessments. The spatial assessments take exiting guidelines or principles for developing elderly-friendly urban environments (Loukaitou-Sideris et al., 2016; Wen et al., 2018; World Health Organization, 2007) one step further by identifying key locations. In planning practices, using indicator-based spatial assessment can help to understand the less-presented stakeholders' preferences for NBR and to convert them into a way that landscape planners can analyze trade-offs among other services or stakeholders (Albert et al., 2014; Hauck et al., 2013).

This model considers several factors to reflect elderly people's preferences in urban contexts, and it results in only a small proportion of lands with a high value regarding recreation opportunities. When compared to the simplified ecosystem service matrix

approach for Hannover (see Section 3.3), our model did not consider most built areas as high recreation opportunities. When compared to a recent study of the ESTIMAP recreation model for Trento (Cortinovis et al., 2018), our model only considers a small proportion of existing green spaces as high recreation opportunities. The possible reasons are twofold. The study applied a landscape aesthetic quality module that addresses human visual experience based on a view extent (Hermes et al., 2018). This approach addresses not only the landscape component but also the diversity in the combination of them. Many urban environments and green spaces are thus identified as lacking the diversity in natural environments. In contrast, the ecosystem services matrix approach and the original ESTIMAP recreation model often depend on the scoring of the individual land cover or environmental feature. Moreover, this study has chosen factors of human inputs that are demonstrated crucial for elderly people's short-trip NBR. The restriction of these facilities might compromise green spaces that are suitable for the general population or purposes.

For the case study in Hannover, our results demonstrate that greenways, lakeside areas, and boundaries of urban forests are often with high recreation opportunities. A possible explanation is that waterfronts and the boundaries of forests have great biodiversity and visual enrichment as different types of landscape components intersect there (Jorgensen, Hitchmough, & Calvert, 2002). Recent studies about elderly people's NBR highlighted the importance of walkways to urban green spaces and trails that connect different green spaces (Artmann et al., 2017; Cerin, Sit, et al., 2013; Zhai & Baran, 2016). Linear greenways and riverside are accessible from a range of locations, so they have a good chance to facilitate the connection of different communities, facilities, and landscapes. Moreover, many areas away from the city center are not well-covered by facilities such as toilets and corner shops. These places on the outskirts of the city have good natural conditions regarding landscape aesthetics, but their potential is not fully pursued due to insufficient facilities and infrastructure.

Except for some scattered and small sites, most built areas, urban farms, and agricultural areas are not found high in recreation opportunities. The results are in accordance with existing findings that many human-dominated ecosystems are at risk of being flat and homogeneous (Peña et al., 2015), leading to a compromise in aesthetics and recreation opportunities. Moreover, places with most demand as well as

most unsatisfied demand are mainly found in a long strip of land across the city center. These areas are densely populated by elderly people and are not in proximity to places with high recreation opportunities. When referring to unsatisfied demand, this study only demonstrated different levels of elderly population density in places that are beyond a walking distance threshold to the nearest high opportunity areas. Therefore, the results are meaningful in analyzing daily short-trip recreation.

Although this study used fine-scaled biotope (natural environments) datasets, the approach is possible to be used in other cities. If there are secondary data of scoring landscape characteristics for aesthetics in the context of interest, a "look-up table" can be built to link the value and available dataset of natural features (or land cover, e.g., Urban Atlas) at the proper scale (Martnez-Harms & Balvanera, 2012).

It should be noted that the assessment of NBR is not just meaningful for the elderly population. Some preferences of elderly people might also speak for children's and other groups' interests, such as maintenance, convenience, and accessibility (Gossett, Mirza, Barnds, & Feidt, 2009; Meshur, 2016). In the green space development, the concept of "universal design" (design for all) are worth considering because they not only can serve elderly people's needs but also can improve other age groups' opportunities to enjoy nature (La Rosa et al., 2018; Meshur, 2016).

3.4.2 Implications

Based on the spatial assessments regarding recreation opportunities, planning suggestions are proposed to improve the urban green spaces. Many elderly people live near the city center of Hannover, but the places with high recreation opportunities are mainly near city boundaries. The spatial mismatches remind planners of the following aspects. While large green spaces are challenging to be added in the densely-population city center, planners can improve the quality of existing community gardens and insert more street parks. These pocket parks are capable to support elderly people's rest and leisure activity if are well-designed with diverse natural features, shades, and seats (Nordh & Østby, 2013; Wen et al., 2018).

Moreover, planners can consider enhancing the connection between existing green spaces with high recreation opportunities. The assessments have emphasized landscape corridors including linear green spaces and lakesides because they can attract a wide

range of residents to walk. By optimizing the network of the high-quality green spaces, more people can be connected, leading to a contribution to environmental justice and social inclusion (Krellenberg, Welz, & Reyes-Päcke, 2014; Tian, Jim, & Liu, 2017). Practitioners can also improve walking paths and intersections along with ways that connect green spaces and residential areas. High-quality walking paths can ease travel difficulties and encourage the elderly to visit green spaces (Cerin, Macfarlane, et al., 2013; Joseph & Zimring, 2007; Zhai & Baran, 2016).

Last, designers and city managers could think about how to enrich the recreational experience in some large urban forests that are identified as flat and homogeneous. This finding is more from a visual perspective, as a previous study has identified that larger urban parks are often found more helpful in mental restoration (Nordh & Østby, 2013). More investigation is needed to understand their recreational potential in addition to the ecological value (Chiesura, 2004).

3.4.3 Limitations

First, when applying the landscape aesthetic quality model, this study referenced a "look-up table" of scoring each landscape component as the best available datasets. However, the source of the scoring table was based on surveys of the general population. This could lead to deviation from elderly people's specific visual preferences. To partial overcome that, we calibrated the model parameter to reflect elderly people's visual experience in urban settings. If there are no time and financial constraints, it is also possible to organize an investigation of local elderly people's visual preferences. Related methods can include interviews, questionnaires, workshops, or public participation GIS (PPGIS). Second, a set of distance thresholds were set in the process of analyzing proximity and the facilities. The choices of distance parameters were mainly based on existing studies addressing walking as we focus on elderly people's daily short-trip recreation on foot. However, elderly people are also likely to travel by bus or other transportation. It is possible that different distance parameters might lead to uncertainty or inconsistent results (Kwan, 2012; Wang & Wen, 2017). Third, for the purposes of informing local planning practices, this study used best available datasets. The transferability of the approach might need more tests regarding generally-available data inputs.

3.5 Conclusions

The paper built a model to map recreation opportunities at the city scale after adapting the ESTIMAP recreation model. Our model considered special factors and parameters to better reflect elderly people's preferences for nature-based recreation at the city scale. It assessed nature-based recreation opportunities by considering landscape aesthetics, various types of facilities, and proximity. The results show that many existing green spaces lack diverse landscape components and the support of facilities, resulting in a compromise in aesthetics and opportunities. Places with high opportunities are mainly found near the lakes in the city south and in the urban forests near the northeast. The high demands are found in a strip of residential areas across the city center, but they are often beyond walking distance to the nearest places with high recreation opportunities. This study suggests that planners should consider planning more small but high-quality street gardens near the city center, enhancing some key greenways and linear green spaces, and improving facilities in aesthetic green spaces near the city boundaries.

More research is needed to spatially investigate elderly people's locally specific preferences for green spaces. Regarding NBR as one type of cultural ecosystem services, how people enjoy nature often depends on local tradition and customs. Moreover, researchers need further consider incorporating the spatial assessments of elderly people's needs into the landscape planning process, where synergies and trade-offs among other development goals must be concerned.

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Conflicts of interest

The authors declare no conflict of interest.

CHAPTER 4. EQUALITY IN ACCESS TO URBAN GREEN SPACES: A CASE STUDY IN HANNOVER, GERMANY, WITH A FOCUS ON THE ELDERLY POPULATION[3]

Abstract

Although assessing equality in green space provision is essential to understand environmental justice, few studies have focused on the age perspective and inequalities in access to nature-based recreation (NBR) regarding elderly people. This study aims at understanding the spatial disparity in access to urban green spaces, with a special focus on the elderly. An enhanced "2SFCA" approach was applied to measure the value of per capita green space by taking into account green space attractiveness, street network, and crowding issues. With a case study in Hannover, Germany, this study tested two scenarios regarding different mobility levels of access to green spaces, attempting to understand elderly people compared to the general population. Our measured value of per capita green space is less compared to that of the traditional "container approach." The distribution of access to green spaces is unequal in both scenarios, and the census blocks near the city center are suffering from relatively low access to green spaces. The scenario of "moderate mobility," which represents elderly people, demonstrated that the distribution of access is even more unequal than the scenario of "better mobility" that represents the general population. Additionally, the bivariate correlation analysis found no evidence that the high share of elderly people in certain census blocks is significantly associated with low access to green spaces. Further studies are suggested to investigate how local contexts play roles in facilitating/obstructing NBR behaviors.

Keywords: Green spaces; provision; inequality; access; population aging; landscape design

[3] This chapter was based on manuscripts submitted to a peer-reviewed journal as Wen, C., Albert, C., Von Haaren, C. Equality in access to urban green spaces: A case study in Hannover, Germany, with a focus on the elderly population

4.1 Introduction

As a growing consensus of environmental justice, planning and managing urban green spaces should better take into account the needs of all demographic groups for nature-based recreation (NBR) (Rigolon, 2017; Wolch et al., 2014). A considerable literature has provided evidence that having leisure activity in green spaces may promote physical activity, mental health, and social contacts (Kaczynski, Johnson, & Saelens, 2010; Tetley & Mountain, 2006; Ward Thompson & Aspinall, 2011; Yung, Winky, & Chan, 2017). Therefore, investigating the provision of urban green spaces plays a vital role in understanding how different social groups in urban areas have access to the public amenities provided by nature (Rigolon, 2016, 2017; Wolch et al., 2014). Traditionally, relevant research from the perspective of planning focuses more on the spatial disparity in the distribution of green space provision, as well as its relationship between people's socioeconomic or ethnicity status (Dai, 2011; Heckert, 2013; Hoffimann et al., 2017; Xiao et al., 2017). Studies have found that the groups of people that are socioeconomically disadvantaged often suffer from fewer opportunities to reach green spaces compared to the relatively privileged groups (Dai, 2011; Hoffimann et al., 2017; Xu, Xin, Su, Weng, & Cai, 2017). Meanwhile, there is growing attention from the gender and age perspective (Comber et al., 2008; Dai, 2011; Kabisch & Haase, 2014; Rigolon, 2017). Especially for the elderly group that is often defined as people aged over 65 according to censuses in many countries, studies often have found that they are less physically active and less engaged in NBR than younger groups (Lee & Maheswaran, 2011; Milanović et al., 2013; Payne et al., 2002; Pleson et al., 2014). Elderly people's functional capacity and mobility are declining, and they are sensitive to environmental barriers and distances to green space for NBR (Kamphuis et al., 2009; Ward Thompson & Aspinall, 2011). Elderly people's access to NBR closely depends on the distribution of parks and whether there are green spaces near homes (F. Gong, Zheng, & Ng, 2016; A. Kemperman & Timmermans, 2014). In this regard, investigating equality in green space provision for elderly people is essential in understanding environmental justice with a focus on the vulnerable groups. For instance, a study in Berlin has measured the value of per capita green space and its distributive equality regarding different social groups, including immigrants and elderly people (Kabisch & Haase, 2014). The researchers found that, although most residents meet the criterion of having access to at least 6 m^2 of green space per person,

elderly people seem to be less present in the studied green sites due to the lack of infrastructure, shade, and diverse naturalness. The assessment also enables local planners to develop an aging-friendly environment to promote public health given the current trend of population aging, in which a growing share of elderly people are expected to live in urban areas (Loukaitou-Sideris et al., 2016; United Nations, 2015; Wen et al., 2018).

Traditionally, many cities and planning authorities have often measured the value of per capita green space using the "container approach," which divides the total green area by population within a boundary (see Rigolon et al., 2018; Xu et al., 2017). While this approach is simple and intuitive, it might neglect either people's movement or the heterogeneity in green spaces (Xu et al., 2017). The container approach is especially problematic for understanding elderly people, who are sensitive to environmental barriers and walking distances (Kamphuis et al., 2009; Ward Thompson & Aspinall, 2011). It was not until recently that a few empirical studies have advanced the spatial assessment of access to green spaces for elderly people at the city scale. For instance, a study conducted a GIS-based assessment of access to green spaces, with a focus on both the elderly and children (La Rosa et al., 2018). It categorized green spaces by size and by the number of features that are preferred by elderly people and children, such as shade areas and facilities. Using a network-based distance threshold, this research has investigated how many people each park can serve. Then, the analysis of proximity and quality of parks can provide suggestions for planning urban green spaces (La Rosa, 2014; La Rosa et al., 2018). A study in Hong Kong has investigated urban green spaces that are accessible for elderly people (F. Gong et al., 2016). By use of size and a landscape fragmentation index of existing green patches, the study has assessed the quality of green spaces and then mapped their respective coverage areas using network analysis. The results have shown the percentage of green area in each district and revealed that small and scattered green spaces play significant roles in improving the elderly's access to NBR in a high-density city (F. Gong et al., 2016). These studies have provided insights to understand elderly people's access to green spaces.

However, the nature of elderly people's walking behavior and preferences of NBR remains unclear in assessing access to urban green spaces. As summarized in two recent review papers (Rigolon, 2016; Rigolon et al., 2018), access to green spaces can be

conceptualized by proximity (distance), acreage (per capita green space), and quality (amenities or facilities). Accordingly, existing studies on elderly people have suffered from the following adequacies. First, few studies on the distributive equality of urban greenery have incorporated different types of green spaces other than parks, and those neglected spaces include lakeside, urban forests, and community gardens. The focus on homogeneous parks may fail to reflect different types of recreational activities and behaviors (Cortinovis et al., 2018). Second, the issue of crowding remains unnoticed when accounting the value of per capita green space. While the green spaces that can serve many people are indeed accessible, they are also likely to be crowded, and this may decrease the recreational offerings per person depending on the quality and size of the green space (Dai, 2011; Rigolon, 2016). The factor of being afraid of crowding in green spaces has been established in many elderly-related studies, and it is worth even better consideration in measuring accessibility (Hung & Crompton, 2006; Wen et al., 2018). Third, existing studies have not yet incorporated a sophisticated framework for assessing landscape aesthetics as a component of green space quality. These potential limitations may affect the understanding of elderly people's preferences and needs for NBR, which often depend on green space attractiveness in addition to size (Artmann et al., 2017; Aspinall et al., 2010; A. Kemperman & Timmermans, 2014; Takemi Sugiyama & Ward Thompson, 2008).

Therefore, the central aim of this study is to assess the spatial disparity in access to urban green spaces, with a special focus on the elderly population. It attempts to overcome the aforementioned limitations by assessing the value of per capita green space for all census blocks across a city, taking into account green space attractiveness, the street network, and the crowding issue. Throughout this study, some key terms or concepts are frequently used. Table 4-1 provides some working definitions of them for clarity.

Table 4-1 Working definitions for key terms in this study

Key term or concept	Working definition
Elderly people	Although defining "elderly" often depends on an individual's physical, mental, and social status, this study simply refers to people over the chronological age of 65 (World Health Organization, 2002). This is due to the age classification in census statistics used for the study.
Urban green spaces	Various types of vegetated land covers in urban settings (Braquinho et al., 2015). This study mainly focuses on open green spaces, including parks,

	grasslands, and urban forests. Notably, wetlands and their associated streams and other blue spaces are also included.
Access to green spaces	By treating urban green spaces as kinds of public resources, this study defines the term access as the possibilities and quantities of green spaces that people in a spatial unit can reach under a given condition (e.g., a distance threshold).
Equality in access	This refers to whether people living in different locations across a city experience spatial disparity in access to green spaces or not (Rigolon et al., 2018). This issue can be further analyzed in the perspective of socioeconomic or demographic characteristics.
Census block	A fine-scale geographical unit for the demographical statistics (in German: Häuserblock), for example, a residential building block.

The research questions are as follows:

- How are green spaces distributed across the study area, considering quantity and quality?
- How equitable is the access to urban green spaces at the census block level in Hannover?
- Does any relationship exist between the share of the elderly population in a census block and its access to green space?

Based on the assessment, planning suggestions are proposed to improve the equality in access to urban green spaces and to better serve elderly citizens' NBR.

4.2 Study design

4.2.1 Overview

The methodological framework has been developed to address the corresponding research questions, including quantifying accessibility, analyzing the disparities, and proposing future plans based on key sites of the assessment results (Figure 4-1). Details of methods are described in the sections below.

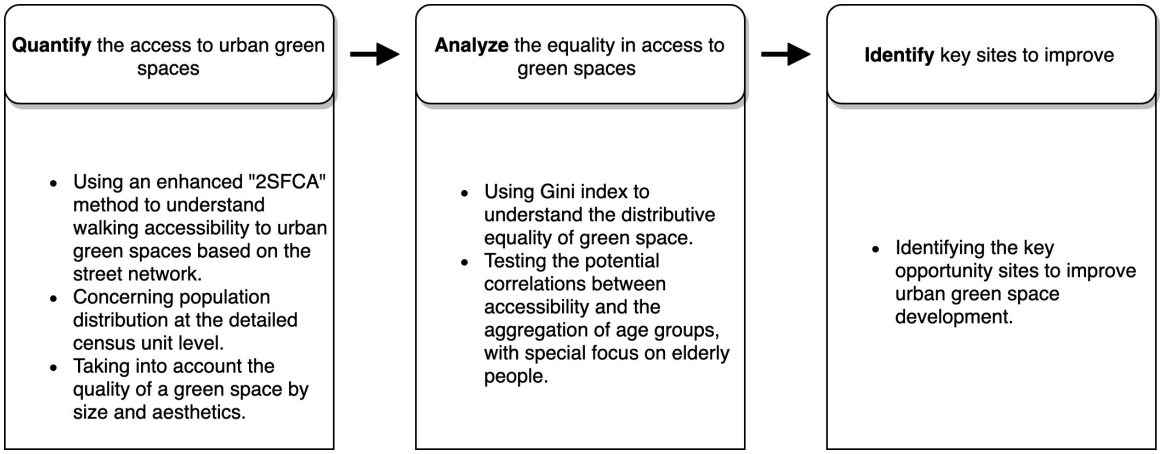

Figure 4-1 Methodological framework for understanding equality in access to green spaces

The selection of the study site is reported in Section 4.2.4. The data used for this study mainly include demographical data and land use data. For the purpose of further differentiating types of green spaces, the data set of natural habitats (biotopes) is applied to extract relevant information in GIS. Specifically, biotopes are the inventory of classified natural features and habitats (Löfvenhaft, Runborg, & Sjögren-Gulve, 2004). Using a biotope data set helps to overcome the limitation that available land use data sets aggregate almost all the natural features into one category in terms of "green space." Moreover, this study took into account the layout of the local street network. Data on walkable roads are incorporated in the GIS analysis from OpenStreetMap, with the help of the Python programming language and the OSMnx open-source software package (Boeing, 2017).

4.2.2 Measuring the access to green spaces

4.2.2.1 Applying the two-step catchment area approach

The "two-step floating catchment area" (2SFCA) method was used to quantify the value of per capita green space of each census block across the study site based on the distance decay effect (Dai, 2011; Luo & Qi, 2009; Radke & Mu, 2000; Zhou & Kim, 2013). The distance decay effect assumes that, compared to further green spaces, nearer green spaces have a larger contribution to the value of per capita green space in a beneficiating census block. The method also accounts for the crowding issue of green spaces. The recreational service that a green place can offer to a catchment area depends not only on its own size and quality but also on how many people in that particular catchment area must share the resources. Therefore, the method advances the traditional

calculation of the value of per capita green space, which usually divides the total green area by population within the boundary (also known as the "container approach," see Rigolon et al., 2018; Xu et al., 2017). Some recent studies have successfully applied this method in assessing access to green spaces at the city scale (Wei, 2017; Wu, Liu, Yu, & Peng, 2018). However, few studies have applied the method to study equality in access regarding older groups, and even fewer have considered the properties of green spaces other than size.

First, the capacity ratio of each green space was calculated based on how many people are within the catchment area of this green space after a distance discount. The closer a census block is to the green space, the less discounted the population of this census block count in this catchment area. When the network distance between the green space and a census block is over the predefined distance threshold, people in this census block do not count as beneficiaries of this green space. The formulas are as follows (Dai, 2011):

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} G(d_{kj}, d_0) P_k}$$

$$\mathrm{G}(d_{kj}, d_0) = \begin{cases} \dfrac{e^{-\left(\frac{1}{2}\right)*\left(\frac{d_{kj}}{d_0}\right)^2} - e^{-\left(\frac{1}{2}\right)}}{1 - e^{-\frac{1}{2}}}, & \text{if } d_{kj} \le d_0 \\ 0, & \text{if } d_{kj} > d_0 \end{cases}$$

Specifically, R_j is the capacity ratio of green space *j* and S_j is the total capacity of green space *j*. In this study, the capacity depends on the green space size and aesthetics. P_k is the population of census block *k*. G is the distance decay function, where d_{kj} is the network distance between census block *k* and green space *j*, and d_0 is the predefined distance threshold, within which this study assumes elderly people are willing to walk for NBR.

Second, the final accessibility value of a census block is the sum of capacity ratios from all the green spaces within its catchment area after using the same distance discount function.

$$A_i = \sum_{l \in \{d_{il} \le d_0\}} G(d_{il}, d_0) R_l$$

4.2.2.2 Considering green space quality by size and attractiveness

In addition to the distribution and quantity of urban green spaces, this study took into account the attractiveness of green spaces. The attractiveness plays a role in deciding the distance threshold for analyzing accessibility, which indicates how far away people can be attracted to visit the green spaces. The assessment of green space attractiveness was conceptualized by size and aesthetics.

Green space size is often considered important to affect people's maximal travel distance for NBR, according to some planning guidelines and related empirical research (Moseley, Marzano, Chetcuti, & Watts, 2013). In general, if a green space is larger, it has better opportunities to attract people from further places, which means a higher distance threshold of accessibility. For example, Natural England published a recommended standard of walking distance corresponding to green space size. According to that standard, residents should have green space of more than 2 ha within 300 m from home, of more than 20 ha within 2 km, and of more than 100 ha within 5 km (Harrison, Burgess, Millward, & Dawe, 1995).

Aesthetics has somehow been neglected in the existing assessments of green space accessibility, but considerable studies have proved that the aesthetic quality of a green space is among the most important factors that are preferred by adults, including elderly groups (Alves et al., 2008; Aspinall et al., 2010; Jorgensen & Anthopoulou, 2007; Leaver & Wiseman, 2016; Wen et al., 2018). For the attractiveness of green space, this study has adapted a landscape aesthetic quality model (for the methodological details see Hermes, Albert, & Von Haaren, 2018). The aesthetic quality was modeled with three components, including a mean aesthetic value of landscape elements in a neighboring environment, landscape diversity, and landscape rareness. The aesthetic values are from 0 to 1 to indicate the aesthetic degree of every place in Hannover city, including both built and natural environments. This study only focuses on green spaces that are larger than 0.5 ha; therefore, a zonal statistical analysis was used to extract the mean aesthetic value for each of the green space patches. Afterward, the zonal means of aesthetics for all green spaces were classified into three ordinal levels using Jenks natural breaks, labeled as "least," "medium," and "most aesthetic" (Table 4-2).

Table 4-2 Green space attractiveness based on green space size and aesthetics

		Aesthetics (in ordinal level)		
		Least aesthetic	Medium aesthetic	Most aesthetic
Green space size (ha.)	0.5–2	Low	Low	Low
	2–5	Low	Medium	Medium
	5 and above	Low	Medium	High

Therefore, the combination of green space size and aesthetics decided its attractiveness. It further established different distance thresholds for analyzing accessibility, which indicates how far away people can be attracted to visit the green space (Table 4-3). This study modeled two scenarios using two sets of distance thresholds. One scenario is for "moderate mobility," in which people are assumed willing to travel 600m, 900m, or 1200m for green spaces depending on the green space attractiveness. The other scenario is for "better mobility," in which the distance thresholds are respectively higher compared to the counterpart in the "moderate mobility" scenario. The two scenarios are developed to understand how different mobility might affect equality in access to green spaces.

Table 4-3 The multi-distance approach, in which the distance threshold of a green space depends on its green space attractiveness

Attractiveness of the green space	Low	Medium	High
Distance threshold for "moderate mobility" scenario	600m	900m	1200m
Long distance threshold for "better mobility" scenario	900m	1200m	1500m

4.2.3 Assessing equality in green space accessibility and its correlation with age groups

To understand the possible equality regarding green spaces, the Gini index is used to measure the distribution of values of accessibility in each census block of Hannover. The Gini index is a widely used indicator measuring inequalities of income and resource allocation, and it has been used in studying urban green spaces (Kabisch &

Haase, 2014; Wüstemann et al., 2017). For any given distribution of values, the Gini index can calculate a coefficient between 0 (perfect equality) to 1 (perfect inequality) of a distribution of values. In addition to its relevance for economics, the Gini index also provides insights in environmental studies and facilitating urban planning that involves spatial justice (Kabisch & Haase, 2014; Wüstemann et al., 2017).

This study calculated the Gini coefficient regarding green space accessibility both for the whole Hannover city and for its thirteen component districts (in German: Stadtbezirk). The Gini at the city level can be helpful as an overview, especially if it is compared to other cities in future studies using a similar method. Moreover, a set of Gini coefficients at the district level can help understand the dynamics of landscape structure and social groups within the city. The applied formula for the city is adopted from the aforementioned studies (Kabisch & Haase, 2014; Wüstemann et al., 2017) as follows:

$$G_{city} = 1 - \sum_{n=1}^{N} \frac{P_n}{P_{city}} * (\theta_n + \theta_{n+1})$$

In the formula, G_{city} indicates the Gini coefficient for the calculated administrative unit, in this case, Hannover city; N stands for the total number of census blocks within this administrative unit; and θ is the accumulative share of the accessibility value (as described in Section 2.2.1) for each census block. Each census block is weighted by the proportion of its population P_n in the total population of the city P_{city}.

Also, bivariate correlations are used to test whether the values of the accessibility to green spaces are associated with any demographic variables, especially age structure. This approach helps us to understand the possible relationship between equality in access to green space and specific social groups. All the data analyses were performed in ArcGIS and the R statistical programming language.

4.2.4 Case study and data set

For this study, we chose Hannover city as the study site. Hannover is the capital city of Niedersachsen and has a population of 540,000. Its share of people over 65 in the total population was slightly under 19% at the end of 2017. Similar to some other big cities in Germany, Hannover is expected to have a higher share of elderly people according

to demographic trends. The local government forecasts that the share of people over 65 is likely to increase to 23% in 2030, as the average age of the population increases from currently 42.4 to 44.3 in 2030 (Landeshauptstadt Hannover, 2018a). This aging process is typical in many big German cities, and it makes Hannover a good example to study the access to green spaces for public goods as NBR, especially to facilitate landscape planning so that more attention can be paid to vulnerable groups.

Table 4-4 Data types and sources

Feature	Data format	Source	Note
Demographic statistics	Tabular	Hannover government (Landeshauptstadt Hannover, 2017b)	Annual statistics on demography at the building block level, from the Hannover government
Biotopes (natural habitats) in Hannover	Polygon	(Drachenfels, 2011; NLWKN, 2011)	Presence of numerous natural features, including water, wetlands, grasslands, forests, gardens
Street network	Polyline	OpenStreetMap	All streets within the administrative boundary of Hannover city, retrieved from OpenStreetMap.
District and census block boundaries	Polygon	Hannover government (Landeshauptstadt Hannover, 2016)	Administrative boundary of Hannover city and each of its census blocks, from the Hannover government

Hannover has been established as a "green city" in Germany, with regard to both total green area and per capita green area (Landeshauptstadt Hannover, 2014). According to the local government, the city's open green spaces, including urban forests, water, and agriculture, cover more than 50% of its total area. The value of per capita green space is beyond 100 square meters (Landeshauptstadt Hannover, 2018b). Despite the good condition, Hannover is also under pressure to balance the potential conflicts of land use between green development and the growing housing demands. The city has recently initialized a plan "*Stadtgrün 2030*" (*City green 2030*) to further strengthen the quality of green and open spaces, which aims to improve public recreation, biodiversity, and the response to urban climate change (Landeshauptstadt Hannover, 2017a). The specific data set used in this study is reported in Table 4-4.

4.3 Results

4.3.1 Equality in the distribution of green spaces in Hannover

The mapping results first help to understand the distribution of green spaces (Figure 4-2). A few large-sized parks and forests are present as stripes in the city's south and northeast. In addition to that, a lot of green spaces that are spreading over the city are small and scattered. The green spaces near residential areas are mainly gardens, graveyards, and a few historical parks. In the south of Hannover are the lake areas and wetlands, and in the east lie some urban forests and agricultural lands.

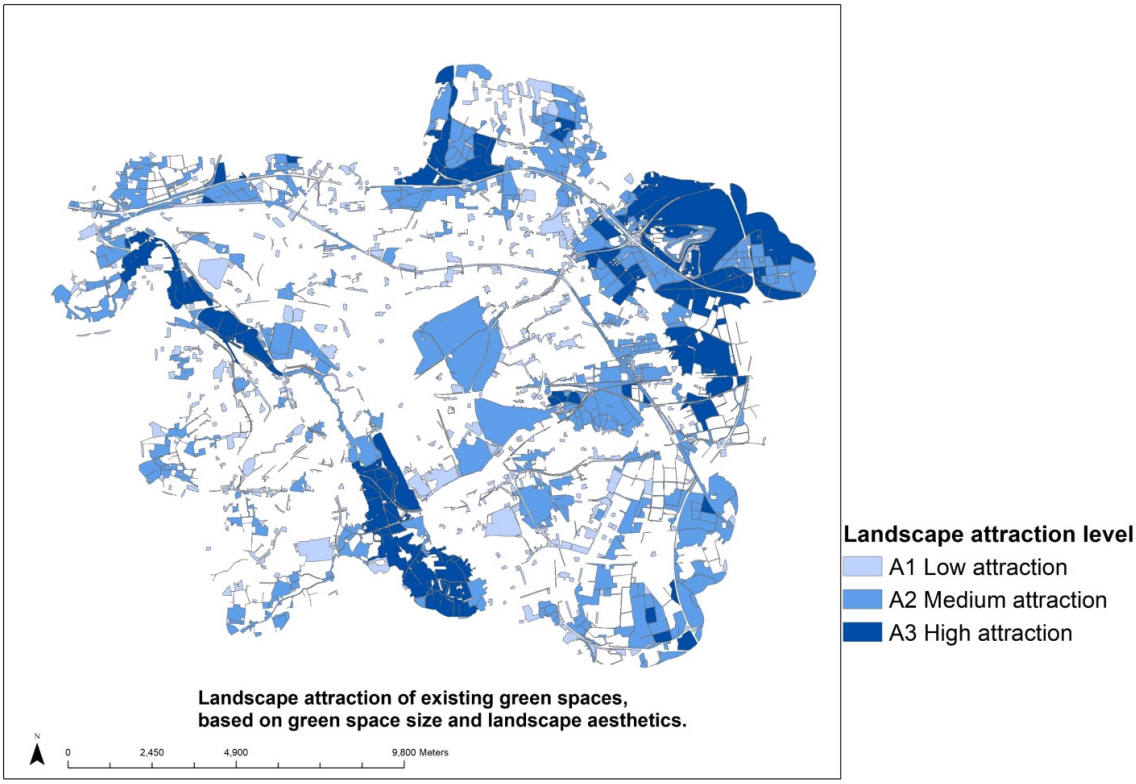

Figure 4-2 Green attractiveness of existing green spaces. The attractiveness depends on green space size and landscape aesthetics.

The descriptive statistics of existing green spaces within each administrative boundary show that, in general, Hannover city has a value of per capita green space around 135 m^2, but the value for each district varies (Table 4-5). However, from the perspective of this "container approach," where people are assumed to enjoy the resources only in the

particular spatial unit, the results show no signs of whether districts with a high share of elderly people have a higher green area or not.

Table 4-5 Demographics and distribution of green space in Hannover city

Code	District (in German: Stadtbezirk)	Population	Elderly population (over 65)	Percentage of elderly population (%)	Green area within the district (m^2)	Value of per capita green space (m^2)
1	Mitte	37,254	5,283	14.18	5,232,184	140.45
2	Vahrenwald-List	70,720	11,717	16.57	601,445	8.50
3	Bothfeld-Vahrenheide	49,667	11,114	22.38	14,228,187	286.47
4	Buchholz-Kleefeld	45,241	10,234	22.62	3,892,633	86.04
5	Misburg-Anderten	33,545	7,309	21.79	14,935,751	445.25
6	Kirchrode-Bemerode-Wülferode	32,069	6,847	21.35	9,034,488	281.72
7	Südstadt-Bult	43,119	7,233	16.77	2,047,439	47.48
8	Döhren-Wülfel	34,512	7,175	20.79	5,879,988	170.38
9	Ricklingen	46,048	9,930	21.56	4,137,651	89.86
10	Linden-Limmer	45,725	5,588	12.22	1,570,629	34.35
11	Ahlem-Badenstedt-Davenstedt	34,467	7,679	22.28	2,426,957	70.41
12	Herrenhausen-Stöcken	36,859	7,036	19.09	8,044,088	218.24
13	Nord	32,435	4,301	13.26	2,149,504	66.27
	Hannover city	541,661	101,446	18.73	74,180,944	136.95

Note: The value of per capita green space is calculated by the "simple container approach," in which green area within a district is divided by its population.

This study modeled the attractiveness of green spaces based on green space aesthetics and size. As a result, the classification of existing green spaces shows that generally, the most attractive green spaces are those near lake areas or historical gardens, where the environments are often natural and diverse. Green spaces with medium attractiveness are city parks, and those with relatively low attractiveness are mostly scattered street green spaces or corner parks.

4.3.2 Disparities in green space accessibility at the district level

Our resulting maps indicate the accessible green area per person for all the census blocks in Hannover. As shown in Figure 4-3, they demonstrate apparent differences in how different parts of the city have access to green spaces. The figures show two modeling scenarios built on two sets of distance parameters, one for the “moderate mobility” scenario and the other one for the “better mobility” scenario.

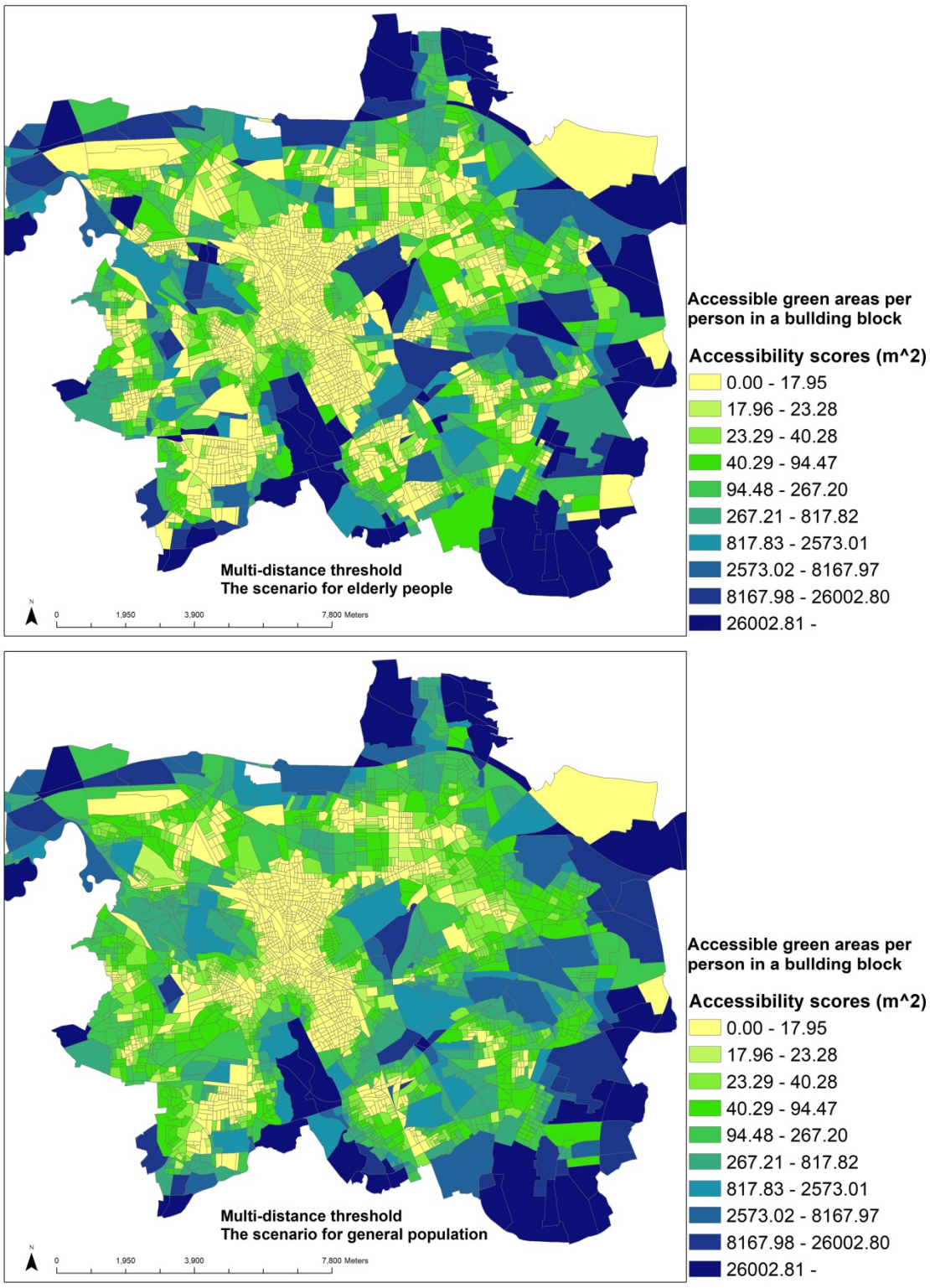

Figure 4-3 Accessible green area per person for all census blocks in Hannover. Two scenarios are presented regarding age groups: “moderate mobility” (above) and “better mobility” (below).

As the reference for comparison, the “better mobility” scenario shows that the city’s median accessible green area per person is 30.2 m^2, weighted by population in each of the census blocks. Specifically, census blocks located in the eastern portion of the city are higher than those in the western portion regarding access to green spaces. Some blocks that are near the zoo and the continuous urban forests have an accessibility value of several hundred square meters. However, many census blocks located in the center or western part of the city have relatively low access to green spaces, such as Vahrenwald-List and Mitte. These densely populated census blocks can only reach less than 10 m^2 of green space.

For the “moderate mobility” scenario, the city’s median accessible green area per person is 30.2 m^2, weighted by population in each of the census blocks. All census blocks have lower access to green spaces than the moderate mobility scenario. The mapping results demonstrate that census blocks near the city center also have low accessibility value; even more, census blocks with low accessibility seem to extend from the city center to a few adjacent communities, including a few populated areas in northern or southern parts such as Bothfeld.

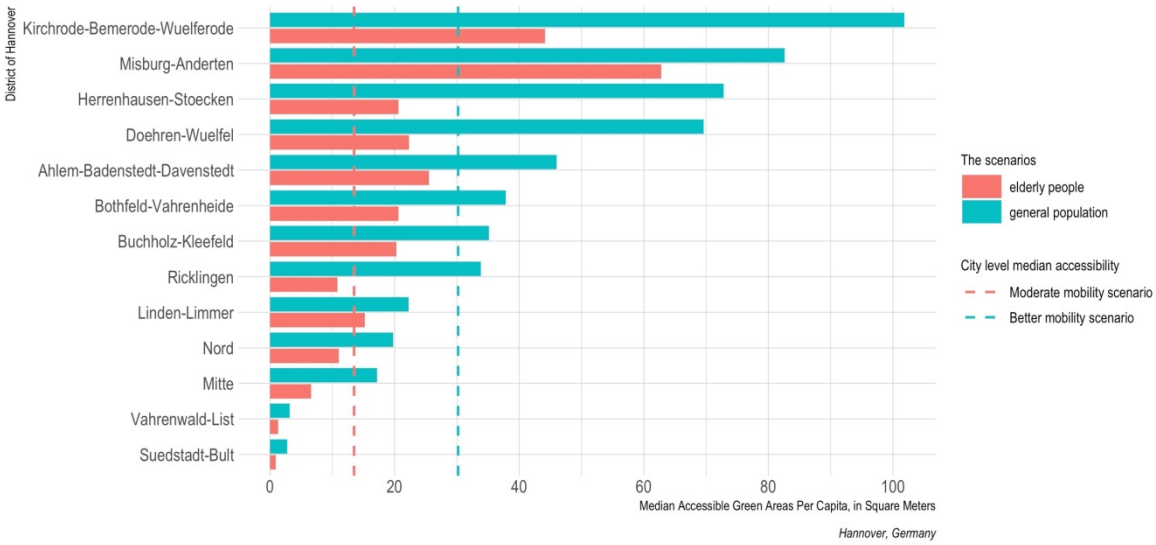

Figure 4-4 Accessibility for two scenarios. Bar chart values indicate the median value of per capita green space in each district in Hannover, weighted by population within its containing census blocks. Dash lines indicate the median value of per capita green space for the whole city, colored by different scenarios.

Table 4-6 Descriptive statistics for green space accessibility in the two modeling scenarios

		"Moderate mobility" scenario		"Better mobility" scenario	
Code	District	Mean (m^2)	Median (m^2)	Mean (m^2)	Median (m^2)
1	Mitte	25.6	17.2	37.4	6.6
2	Vahrenwald-List	33.5	3.1	32.7	1.3
3	Bothfeld-Vahrenheide	166.9	37.8	145.4	20.6
4	Buchholz-Kleefeld	128.2	35.2	93.4	20.3
5	Misburg-Anderten	371.1	82.6	209.9	62.8
6	Kirchrode-Bemerode-Wuelferode	223.8	101.8	191.6	44.1
7	Suedstadt-Bult	55.2	2.8	57.6	0.9
8	Doehren-Wuelfel	179.6	69.6	177.4	22.3
9	Ricklingen	129.0	33.9	97.5	10.8
10	Linden-Limmer	35.5	22.3	28.3	15.2
11	Ahlem-Badenstedt-Davenstedt	79.4	46.0	76.6	25.5
12	Herrenhausen-Stoecken	255.1	72.8	228.9	20.6
13	Nord	65.6	19.8	65.6	11.1
	Hannover city	124.5	30.2	103.3	13.5

Note: The aggregate statistics for districts are weighted by the population of census blocks that are within the districts.

From the results of two modeling scenarios, some districts are sensitive to the distance thresholds regarding access to green spaces (Figure 4-4). For example, census blocks in districts like Herrenhausen and Stoecken can have a median accessibility value of about 72.8 m^2 in the general population scenario (Table 4-6). However, their access to green spaces sharply decreases to only 20.6 m^2 when in the elderly people scenario. When people who are living in these areas can increase walking distances somehow, they are likely to reach much more green space nearby. Meanwhile, some places are low in access to green spaces regardless of the two scenarios, like Vahrenwald-List Suedstadt-Bult, indicating a lack of green space resources in a relatively large range.

Additionally, our results find that, when aggregating data from census blocks to the district that they belong to, the resulting statistics are sensitive to whether one uses median or mean accessible green area per person as the measurement, although both are weighted by population in the census blocks. Mean values are often larger than median but are much more likely to be influenced by extreme values. Therefore, the median value provides a robust alternative to represent the average level of accessibility in population for the unit of analysis.

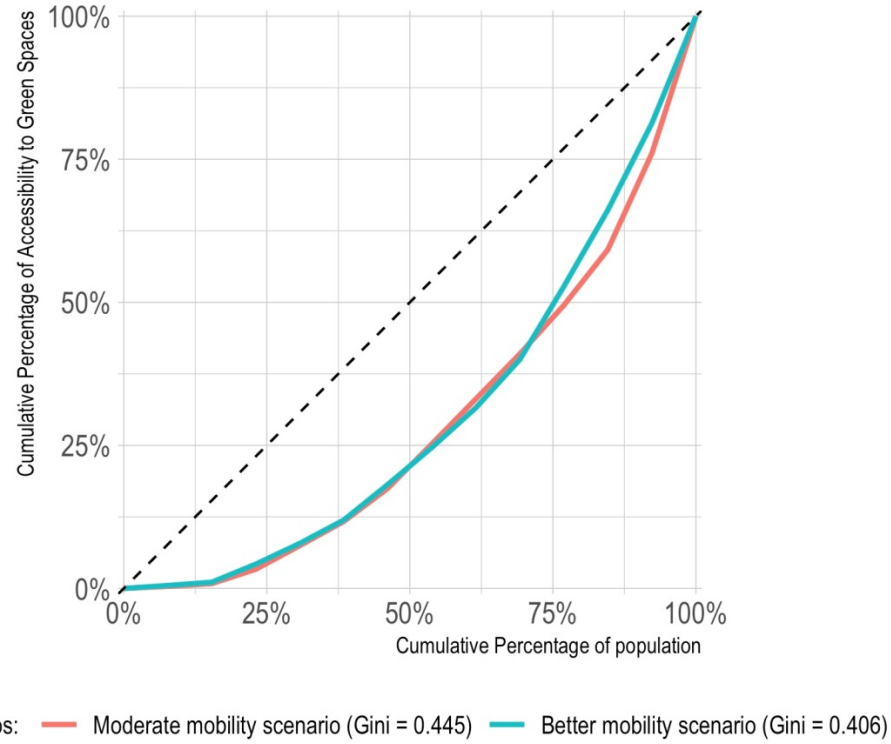

Figure 4-5 Gini coefficient and Lorenz curve for the two scenarios of accessible green areas per person across all census blocks in Hannover. The Gini coefficient is a number between 0 (perfect equality) and 1 (perfect inequality) to indicate the inequality in access to urban green spaces (Wüstemann et al., 2017). The results show that in the "moderate mobility" scenario, inequality is worse than in the "better mobility" scenario.

The Gini coefficient and the Lorenz curve are used to describe the inequality of accessible green area per person (Figure 4-5). For the "moderate mobility" scenario, the Gini coefficient is 0.445, which is larger than the Gini coefficient of the "better mobility" scenario. When people are assumed to tend to walk less distance for NBR, the degree of inequality regarding access to green spaces appears to be deepened.

4.3.3 Age disparities in green space access

A bivariate correlation was used to test whether a census block with a high share of a certain age group is associated with high access to green spaces (Table 4-7). The tests for two scenarios find that considering the significant levels, the percentage of elderly people (65 and above) shows a slightly positive association with access to green spaces in both scenarios. Therefore, the results show no statistical evidence that elderly groups are associated with low access to green spaces. Interestingly, the results also show that the percentage of youth (18–30) is negatively associated with access to green spaces, also in both scenarios regarding distance thresholds.

Table 4-7 Bivariate correlation between age percentage and access to green spaces across all 3,092 census blocks in Hannover

	Correlation coefficient between age percentages and green space accessibility	
Age group	"Moderate mobility" scenario	"Better mobility" scenario
0–17	0.102**	0.137**
18–30	-0.244**	-0.290**
31–64	-0.028	-0.029
65–above	0.097**	0.142**

** indicates significance at the 0.01 level

4.4 Discussion

4.4.1 Understanding equality in access to urban green spaces

This study investigated access to green spaces across all 3,000 census blocks in Hannover, with the green space distribution, size, attractiveness, and crowding issues being considered. It tested two scenarios regarding different mobility levels, which represent elderly people and the general population, to understand how equal the access is. The results found that the distribution of access to green spaces is unequal in both scenarios, and the census blocks near the city center are suffering from relatively low access to green spaces. The scenario of "moderate mobility," which represents elderly people, demonstrated that the distribution of access is even more unequal than the scenario of "better mobility." Additionally, a bivariate correlation analysis found no evidence that the high share of elderly people in certain census blocks is associated with low access to green spaces.

Our results highlighted that, by using a network-based multi-distance approach, the calculated accessible green area per person is somehow less than the measurements by the "container method," in which green area within a district is divided by its population (Table 4-5, Table 4-6). The difference can be explained by the methodological details. When using the method based on catchment area to measure accessibility, the smallest analyzing unit is each of the 3,000 census blocks in the city. The access value of any district represents its containing census blocks that are weighted by population. If many populous census blocks do not have adjacent green spaces, they may bring down the value for the district containing them. Likewise, the detailed spatial scale reveals that, although some census blocks do have high value regarding access to green spaces, their population may not be high and thus not be representative, such as some places near the eastern boundary. Therefore, compared to the commonly used container approach, this assessment is more sensitive in revealing the inner inequalities of a district. This finding corresponds to existing concerns about the container approach that it is restricted to the boundaries and is averaging inner difference (Rigolon et al., 2018; Xu et al., 2017). Another explanation might be that the multi-distance approach takes account of the crowding issue. Some parks can be reached by a large number of people, so their capacities to contribute to the value of per capita green space are compromised and lowered.

The resulting median accessibility value at the city level, which is 25 m^2 accessible green area per person, can be used to compare with other existing research that has measured access to green spaces in Hannover. For example, two recent studies measured access to green spaces in many big German cities (Grunewald et al., 2017; Wüstemann et al., 2017). One used 100m gridded population tiles and found that for Hannover the median value of per capita green space within a 500m Euclidian distance is 8.3 square meters (Wüstemann et al., 2017). Although our study used larger distance thresholds and has higher resulting values, both studies demonstrate that, when focusing on a finer scale such as streets and blocks, the estimated accessibility is lower than the container approach. Consequently, for planners who often base their decision making on spatial assessment, it is important to be aware of how different measurements might affect the understanding of green space provision and accessibility.

From the results of two modeling scenarios, we found that access to green spaces across the city is more unequal in the "moderate mobility" scenario that attempted to represent elderly people. When people tend to walk a shorter distance for NBR or have lower mobility, not only would they have less value of per capita green space, but also the equality in access to green spaces across the city becomes worse. Both scenarios reveal that people in the city center have very low access to green spaces.

By applying the Gini index, this study echoed some existing studies using similar methods to understand inequality in access to green spaces. For instance, a study in 2017 measured the green space accessibility for each of the 53 major cities in Germany (Wüstemann et al., 2017). By applying the Gini index, the researchers found strong disparities in green space provision across the country. Although our study focuses on one city and the inner inequality across its districts, both studies found that Gini coefficients are helpful in understanding the distributional equality of urban green spaces. Another study in 2014 investigated the distributional equality of urban green spaces within Berlin, with a special focus on different social groups including elderly people, children, and immigrants (Kabisch & Haase, 2014). Researchers found that, although all residents and elderly people seem to have a lower Gini coefficient regarding the distribution of urban green spaces, some immigrant groups have the highest Gini, indicating a highly unequal status. Our studies further demonstrate the necessity to investigate the potential inequality in the perspective of demographic characteristics (Wolch et al., 2014).

The correlation analysis shows no evidence that census blocks that have high shares of the elderly population are significantly associated with relatively low access to green space. However, we did find that the aggregation of young adults (18–30) has a correlation with low access to green spaces (Table 4-7). Existing studies in different contexts have often found inconsistent evidence for whether groups of people that are socioeconomically disadvantaged have lower access to green spaces (Kabisch & Haase, 2014; Rigolon, 2016; Rigolon et al., 2018; Wolch et al., 2014; Xu et al., 2017). One possible explanation for this study is that, due to the urban planning and historical contexts, universities and job opportunities are mainly near the city center, where the green spaces are relatively scarce.

4.4.2 Implications

For local planners, it is important to be aware of equality in access to green spaces. Different city locations may need different strategies to improve accessibility. The results of the spatial assessment have identified key locations for optimizing the distribution of green spaces. Areas near the city center only have low access to green spaces. Although it is hard to add large green spaces, landscape planners can improve existing pocket parks and to strengthen linkages between nearby green spaces. A complete green network can ease the walking for recreation and thus to alleviate inequality in green space distribution. Hannover has already built a walkway named "red thread" to connect the city's places of interest for tourism. The roads along the "red thread" are designed to be walkable, safe, and clearly marked. Similar ideas can be applied to populous built areas where elderly people suffer from low access to green spaces. Moreover, the access to green spaces in some districts (e.g., Herrenhausen and Stoecken) is sensitive to a distance threshold as modeled in the two scenarios. One strategy may be improving the public transport connection between the densely populated residential areas and parks. As these areas are not in the city center where space is limited to develop green spaces, planners can also consider adding new gardens nearby.

4.4.3 Limitations

This study includes several main limitations. First, the study applied two sets of distance thresholds to study accessibility, but the choices of numerical parameters are mainly referenced to the literature and are interpreted by the authors. Future studies may include field studies in different locations of the city to investigate the lengths to which targeted groups of people, in this regard elderly people, are willing to travel for NBR. Second, because of a strict data privacy policy, this study was only authorized to use the age structure data at the census block level. Therefore, it didn’t explore the relationship between access to green spaces and other socioeconomic characteristics of the population. Third, for analytical convenience, when taking into account the quality of green spaces, this study only considered green space attractiveness based on size and landscape aesthetics. For further studies regarding access to green spaces, it may be possible to examine more factors that reflect people’s travel and recreational behaviors, such as facilities, management, and safety issues.

4.5 Conclusions

Although assessing equality in green-space provision is essential to understand environmental justice, few studies have focused on the age perspective and inequalities in access to NBR regarding elderly people. This study has assessed the spatial disparity in the distribution of green-space provision, with a special focus on elderly groups. It advanced the traditional "container approach" of measuring the value of per capita green space by taking into account green space attractiveness, the street network, and crowding issues. The results found that the value of per capita green space is less compared to the traditional "container approach." The distribution of access to green spaces is unequal in both scenarios, and census blocks near the city center are suffering from relatively low access to green spaces. The scenario of "moderate mobility," which represented elderly people, demonstrated that the distribution of accessibility is even more unequal than the scenario of "better mobility." The bivariate correlation analysis found no evidence that the high share of elderly people in certain census blocks is associated with low access to green spaces.

When assessing access to urban green spaces, further studies are encouraged to survey how elderly people have NBR in different locations of the city and why they would make the decision. The field surveys can be valuable to compare the results of indicator-based spatial assessment, especially in revealing how local contexts play roles. For example, local festivals, cultural landscape, and group activities can be attractive to elderly people and encourage their willingness to walk, but the role of these activities is not yet fully explored in measuring access to green spaces. To improve the equality in access to urban green spaces, future studies should not only focus on the distribution of green spaces but also how they may fulfill different needs. The complex nature of elderly people's NBR calls for more efforts to address the cultural and emotional ties to green spaces, as well the sense of place.

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Conflicts of interest

The authors declare no conflict of interest.

CHAPTER 5. SYNTHESIS AND CONCLUSION

5.1 Summary of findings

This thesis aims to provide a systematic understanding of elderly people's preferences for NBR, to spatially assess NBR opportunities and demands, and to investigate the equality in access to NBR for elderly people. It has answered three main research questions: (1) What landscape characteristics and green space features are preferred by elderly people? (2) What recreation potentials, opportunities, and demands of elderly people for NBR exist in the Hannover urban area? (3) How equitable is the access of the elderly to green spaces at the census block level in Hannover? Considering NBR as a service provided by landscape (Albert et al., 2016; Burkhard et al., 2014), this thesis starts from the demand-side and generates knowledge of people's preferences for NBR. It then assesses the process of service delivery by spatially assessing how different conditions of urban green spaces serve the elderly. The proposed spatial assessments shed light on the interaction between elderly people and urban green spaces. As landscape planning is a multi-disciplinary platform and a "social-action with knowledge" (Ahern, Cilliers, & Niemelä, 2014), it accounts for achieving public good by setting relevant environmental objectives and measures (Von Haaren & Albert, 2011). Thus, the planning process would benefit from the knowledge of its users and beneficiaries.

The results mainly consist of three parts: a systematic summary of evidence of elderly people's preferences for NBR, a spatial assessment built on the ESTIMAP recreation model to understand potential, demands and opportunities regarding elderly people and a spatial investigation of equity in access to green spaces. Taken individually, each of them responds to one key theme related to population aging. As a whole, they act as a process in facilitating planning, in which the measurements of elderly people's NBR are defined, operated and evaluated.

Chapter 2 explores existing scientific evidence of elderly people's preferences for NBR and proposed planning suggestions accordingly. Using a systematic literature review based on the PRISMA method, this study analyzes in-depth 44 peer-reviewed articles that were published between 2000 and 2017. The results show that the topic has received increased attention across disciplines and researchers all over the world have

used various research methods, including questionnaires, interviews, experiments, observations, GIS or mixed methods. Different types of green spaces, parks and neighborhood greenery have been investigated extensively for the use of elderly people. Researchers have paid most attention to elderly people's recreational activities, including walking, sitting and using facilities. Based on the categorization of basic human needs (Max-Neef, 1992), researchers have identified "subsistence", "leisure" and "protection" as the top three needs for elderly people in NBR. This study proposes a framework of elderly people's preferences for landscape characteristics based on evidence. The framework consists of four categories: landscape features (e.g. aesthetics, legibility, and cultural heritage), infrastructure and facilities (e.g. trail, recreational facilities, and business settings), maintenance (e.g. cleanliness and security) and accessibility. This study synthesizes existing research evidence and advances the understanding of planning for elderly people in several aspects. In addition to general preferences for aesthetics, safety and convenience, existing research has also reported inconsistent results of preferences in different contexts. Examples include "inclusive parks versus elderly-specific parks", "diverse land use versus single land use", and "high connectivity versus low connectivity." Not surprisingly, elderly people in different contexts often have different relative importance of preferences. The findings of this study can provide a framework of preferences as a knowledge inventory.

Chapter 3 develops a spatial assessment of recreation potential, opportunities and demands with regard to the elderly population. The assessment is built on the ESTIMAP recreation model considering elderly people's preferences for NBR in urban areas as well as the data availability on a city scale. This study conceptualizes recreation potential in terms of landscape aesthetics, which is assessed by a multi-layered landscape aesthetic quality model. It then assesses recreation opportunities by cross-tabulating different conditions of recreation potential and human inputs (e.g. facilities and proximity). Therefore, the assessment reflects elderly people's preferences for both natural features and the necessary supporting infrastructure. The assessment demonstrates its usability with a case study in Hannover, Germany. Results reveal that although the city has many urban parks, only a few of them offer high potential for elderly people. Green spaces with high potential are those found with diverse landscape components or near the water features. When taking into account human inputs, the

results show a clear spatial pattern. Several linear corridors are found with the best recreation opportunities for elderly people. These corridors stretch from the western to the southern part of the city, linking royal parks, wetlands and lake areas. Other areas with high opportunities are mainly found near the eastern boundaries of the city. However, the facilities that serve elderly people's needs are concentrated in a long strip of land across the city center, which is beyond walking distance to the areas with high recreation opportunities. It should be noted that the recreation opportunities are based on proxy indicators and these do not represent the actual usage of the places. This is because the actual data regarding elderly people's daily recreation is unavailable. Therefore, a well-established ecosystem services matrix approach is used to compare the assessment results of NBR (Burkhard et al., 2014). The results can be helpful for local planners to understand how different conditions of environments serve elderly people's NBR.

Chapter 4 investigates equality in access to urban green spaces in Hannover, with a focus on the elderly population. This study advances the traditional approach of measuring per capita green spaces by applying an enhanced "2SFCA" approach. This enhanced approach takes into account attractiveness of green spaces, the actual street network and crowding issues. It tests two scenarios that represent two mobility levels with respect to elderly people and the general population. The results show that in either scenario, the per capita value calculated by the enhanced "2SFCA" approach is less than that of the traditional "container approach". In the scenario of "moderate mobility" (for elderly people), the per capita value in each census block is less than that in the scenario of "better mobility" (the general population). Moreover, the results show the inequality in access to green spaces using a Gini coefficient. The "moderate mobility" scenario shows a more uneven distribution of access across districts of Hannover. The bivariate correlation analysis shows no evidence that census blocks with a higher percentage of the elderly population suffer from worse access to urban green spaces. These results contribute to the understanding of environmental justice in the perspective of age. Although this study does not find elderly people to be disadvantaged in terms of access to NBR, it provides an approach to understand the equality in access to urban green spaces. This study therefore proposes a planning recommendation to help people who have the least access to green spaces.

5.2 Discussion and conclusion

5.2.1 Advance understanding of elderly people's NBR

By targeting a specific group of citizens as beneficiaries, the thesis frames a series of procedures to understand elderly people. It synthesizes evidence of elderly people's preferences for NBR ("what to consider and why"). The evidence forms a framework to inform practitioners about how different landscape characteristics might attract and disturb the elderly. Then spatial indicators of the identified key factors can be developed to model recreation potential and opportunities ("how to spatially examine"). Considering the best available data in the local context, the thesis assesses equality in access to NBR ("whether the amenities have an uneven distribution"). The assessments analyze the interaction between elderly people, natural features, facilities, and proximity. The maps demonstrate spatial patterns of elderly people's NBR to communicate with different stakeholders (Casado-Arzuaga et al., 2013; Egarter Vigl, Depellegrin, Pereira, de Groot, & Tappeiner, 2017).

The thesis advances understanding of elderly people's preferences for NBR in the perspective of landscape planning. Previous studies of elderly people mainly focused on urban parks, physical activity, and the obtained benefits. The study synthesizes diverse evidence of preferences for NBR by different activities, green spaces types and landscape characteristics. It organizes both general preferences and special preferences for landscape characteristics including landscape features, infrastructure, maintenance and accessibility. The general preferences are more likely to be favored by elderly people across contexts and are suggested in planning practices; the special preferences serve as a reminder about the complexities of elderly people's NBR. The special preferences highlight the fact that elderly people might have different attitudes and requirements for the same landscape characteristic, depending on the activity types and surrounding environments. For example, elderly people often like dense woodlands in urban areas as they provide the sense of immersion in nature, but only if they do not breed crime and raise safety concerns (Alves et al., 2008; Artmann et al., 2017; Jorgensen & Anthopoulou, 2007). The understanding of preferences connects planning practices with research of elderly people's needs.

The thesis then reveals the spatial patterns of elderly people's preferences for NBR in the city. Elderly people, as a vulnerable group, are often less-present in the planning

process and previous research seldom demonstrated elderly people's needs and concerns in a spatially explicit way. This study maps the different conditions of the urban environment for NBR. The spatial patterns convey elderly people's preferences and concerns so that decision-makers can better understand where key locations are and what the consequences might be if a development plan is implemented. Moreover, the maps of recreation opportunities examine the spatial relationship between different factors. For example, recreation opportunities have identified combinations of different levels of landscape aesthetics and human inputs. These cross-tabulations can inform practitioners of synergies between support conditions for NBR. For example, aesthetically pleasing urban forests might be compromised by poor facilities and accessibility. The spatial patterns of different thematic maps enable planners to understand the complexity in planning for elderly people's needs for NBR (La Rosa et al., 2018; Loukaitou-Sideris et al., 2016; Wen et al., 2018).

Although focusing on elderly people, the thesis facilitates understanding of the relationship between the elderly and other social groups. In planning practices, conflicts can exist in different ecosystem services and development objectives among stakeholders (King, Cavender-Bares, Balvanera, Mwampamba, & Polasky, 2015; Seppelt, Dormann, Eppink, Lautenbach, & Schmidt, 2011). Sharing the same urban environment, the elderly population might have different requirements or priorities to younger groups with regard to environment features. NBR can conflict with other environmental objectives when reallocating limited urban space for building green infrastructure (Wagner, Mager, Schmidt, Kiese, & Growe, 2019). Considering conflicts, the thesis only offers a perspective of elderly people. It is not arguing that it is trivial to deal with the conflicts among other stakeholders or services. However, it is beyond the scope of this thesis to analyze the complex trade-offs. Even though there are planning tools to facilitate trade-offs, one key premise is to present the vulnerable groups' ecological interaction with nature. Moreover, the elderly-friendly environment does not mean elderly-only. Elderly people often have different priorities in their preferences regarding specific landscape characteristics, but they do share common ground with other age groups (Joseph & Zimring, 2007; Payne et al., 2013; Pettebone et al., 2011). Demographic changes are dynamic, as everyone eventually grows old (World Health Organization, 2002). People's needs for public health care and social inclusion through NBR matter in any social context. Therefore, some identified

preferences and spatial patterns are also meaningful to other social groups regarding human inputs and opportunities. For example, children and wheelchair-users can also benefit from efforts on improving accessibility, convenience, and maintenance of urban green spaces.

The topic of environmental justice is receiving growing attention (Rigolon, 2016; Wolch et al., 2014) and this thesis attempts to respond in an age perspective. Existing research has proposed key pillars of environmental justice – distribution, recognition and participation (Chaudhary, McGregor, Houston, & Chettri, 2018). Focusing on the elderly population, the thesis mainly contributes to the understanding of distribution (by spatial assessments) and recognition (by the systematic literature review). With regard to distribution, Chapter 3 maps the different conditions of recreation potential and opportunities in the city. The results demonstrate the uneven distributional patterns of recreational suitability. Planning practitioners should be aware of where there is a mismatch between the elderly population and recreation opportunities. Regarding NBR as social-ecological wellbeing, the disadvantaged groups should have access to the green spaces (Fisher et al., 2014). Chapter 4 advances the understanding of distribution by considering access. Access to green spaces is a necessary alleviation and compensation to distributive inequality as it considers human mobility. The results found no significant statistical evidence proving that a high proportion of elderly residents is associated with relatively low access to green spaces. However, the study has confirmed the uneven distribution of access to urban green spaces in both scenarios regarding different walking mobility. The elderly population who might suffer from relatively low mobility are more likely to be restricted to accessing areas near their residence, leading to lower chances of overcoming the distributive inequity of existing green spaces.

5.2.2 Plan the landscape in response to population aging

A spatial assessment of elderly people's preferences can help to create a basis for green space planning. At the city scale where green spaces are parts of urban green infrastructure, planning practitioners should first consider approaches to integrate elderly people’s preferences into landscape planning. While existing evidence and best practices are worth considering, it is vital to develop a communication channel to incorporate the local vulnerable groups’ needs and to utilize them as a basis for

landscape planners to create a planning strategy. Existing tools of ecosystem services are promising to assess stakeholders' preferences, map them and facilitate trade-offs among other services or stakeholders (Albert et al., 2014; Hauck et al., 2013). Therefore, by using multiple approaches, such as stakeholder analysis, biophysical modeling, cognitive mapping and scenario developing, local practitioners can better understand the overview state of elderly people's NBR and the spatial patterns of different conditions. In this case, as described in Chapter 5, Hannover has initialized a city-green project aimed at improving the services of urban green spaces and it welcomes the knowledge of citizen science (Landeshauptstadt Hannover, 2017a). Then plan-making can be undertaken based on awareness of the identified key locations, where there are hotspots or mismatch between opportunities and demands. In terms of population aging, the provided assessment frameworks can facilitate the green space development.

The distribution of urban green spaces should be optimized to fulfill elderly people's demands and to alleviate inequality in access to areas with high recreation opportunities. Based on the spatial assessments regarding recreation opportunities, the study offers planning suggestions to improve the urban green infrastructure. In Hannover, a large number of elderly people live near the city center, but the places with high recreation opportunities are mainly near city boundaries. The spatial mismatches remind planners of the following aspects. Whilst it is challenging to add large green spaces to the densely-population city center, planners can improve the quality of existing community gardens and insert more street parks. These pocket parks are capable of supporting elderly people's rest and leisure activity if they are well-designed with diverse natural features, shade and seats (Nordh & Østby, 2013; Wen et al., 2018). Moreover, planners can consider enhancing the connection between existing green spaces and high recreation opportunities. The assessments highlighted landscape corridors including linear green spaces and lakesides because they can attract a wide range of residents to walk. By optimizing the network of the high-quality green spaces, more people can be connected, leading to a contribution to environmental justice and social inclusion (Krellenberg et al., 2014; Tian et al., 2017). Practitioners can also improve walking paths and intersections along with ways to connect green spaces and residential areas. High-quality walking paths can ease travel difficulties and encourage the elderly to visit green spaces (Cerin, Macfarlane, et al., 2013; Joseph & Zimring, 2007; Zhai & Baran, 2016).

Facilities and infrastructure are vital to urban green space development. Many green spaces are aesthetically pleasing, and their NBR potential can be better pursued by improving facilities and infrastructure. For example, green spaces near the eastern boundaries of Hannover have high value in landscape aesthetics, but they lack facilities such as toilets and corner shops. The potential of these green spaces can be achieved by improving facilities and the accessibility.

5.3 Limitations

This thesis has a few methodological limitations. Firstly, with regard to the systematic literature review, the synthesized evidence might be at risk of bias in the scope of the articles discussed. One major concern is that the review only considers peer-reviewed journal papers that are written in English. It is possible that some important evidence published as reports, books or documents was overlooked.

Secondly, due to the problem that the data of elderly people's NBR is often unavailable at a fine scale, the thesis uses some best available data as proxies. When building the assessment framework of recreation potential and access, this study introduces a landscape aesthetic quality model to link perceived aesthetic values and landscape components. However, as explained in Chapter 3, the data source used for operating this model is based upon existing surveys of the general population. Although this study considers the best available dataset and other model parameters to better reflect elderly people's visual preferences for landscape characteristics, the limitations cannot be fully removed. Similarly, this study was not able to obtain detailed data of accidents for modeling the fear of danger. It only uses green space maintenance and the proximity to facilities and shops, based on the assumption that surveillance by "eyes on the street" often plays a role in safety (Jacobs, 1961).

The thesis only considers elderly people's short-trip recreation on foot, meaning it may neglect possible long-distance travel for recreation. For daily trips, the location and distribution of urban green spaces play a dominant role in affecting access. However, when considering other modes of transport, such as bus, trams and private cars, elderly people can significantly expand their scope of activity and have better chances for NBR. These possibilities would introduce a more complex but accurate understanding of

environmental justice. The reflection is that the choice of distance parameters could lead to uncertainty or inconsistent results (Kwan, 2012; Wang & Wen, 2017).

The thesis chose Hannover, Germany as a single study case. While assessments and mapping tools are built on standard approaches with transferability in mind, the methodological framework was only tested in a single study area. Therefore, it would be useful to investigate other cities at scale. The most eminent problem is data availability. There are indeed open-source data sets for landscape components (e.g. categorized satellite images), street network (e.g. OpenStreetMap) and spatial demography (e.g. European data portal). However, assessing NBR at the city scale often needs fine-scale data. The study is authorized to use the data of biotopes that have detailed classification of natural features. It also references the city's data inventory of toilets, open space management and exercise facilities. Other cities may not have the same form of data. Therefore, studies for other cities need to pre-process available data for best serving particular research proposes.

5.4 Suggestions for future studies

Future studies should examine more closely how cultural contexts of cities would affect elderly people's preferences for NBR. When considering a group of stakeholders' needs in the landscape planning, planners and researchers often seek evidence and explanation of how they interact with nature for wellbeing (Ekkel & de Vries, 2017). Although there is a growing number of studies on elderly people's preferences, practitioners should investigate how local cultural contexts differ and to what extent scientific findings of preferences can be representative to local people. Therefore, more studies are encouraged to explore how local festivals, cultural landscape and group activities can play a role in NBR for elderly people. Possible methods include in-depth interviews, questionnaires, workshops or public participation GIS. Recent research of "sense of place" on elderly people offers greater understanding of the context of place attachment (Phillips et al., 2011), but researchers still need to look further at how this influences NBR.

Future studies should also explore how elderly people's needs can be considered in the landscape planning process, especially amid potential conflicts of interests with other age groups. The thesis identifies that elderly people's requirements for green spaces

might differ from young people's requirements. Some questions can be raised. For example, when the space is limited, whether developing elderly-specific green spaces should have a higher priority than the green fields for teenagers, and how to solve the conflicts of demands between different social groups. Future studies can use different tools to analyze different demands for nature. For instance, the framework of ecosystem services can provide a theoretical basis and platform to assess and trade-off the demands of stakeholders' into planning (Albert et al., 2016; Wolff et al., 2015). It is possible that elderly-specific parks can result in social segregation instead of social inclusion. When elderly people's demands can also be relevant to other social groups, planning practices have a better chance to improve the conditions of NBR for all citizens.

Finally, with regard to the spatial assessment of elderly people's NBR, future studies are suggested to consider temporal and spatial dynamics of demographic changes. The distribution of NBR opportunities and the demands of elderly people are likely to change every few years. Therefore, assessment of elderly people's NBR must consider the change of demands (Wolff et al., 2015). More studies are needed to stress how demographic changes can be considered into sustainable landscape development.

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When I received the schedule of my thesis defense, I was on a train, seeing the vast farmland through the window. I still remember the mixed feelings with happiness and relief.

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Doing the doctoral study is hard. Before you can simply immerse yourself in reading the literature and analyzing the data, many things have to be taken care of. The (third) language barrier, the pressure management, the never-ending self-doubt, and not to mention the critics from reviewers. Sometimes, I felt like I'm walking alone in the snow at night, being free but chill. Fortunately, my supervisors, Prof. Christina Von Haaren and Prof. Christian Albert, provided tremendous help. On the one hand, they always respect my academic interests and encourage me to focus on methods that I chose by myself. I really enjoy the freedom of learning whatever I want. One the other hand, they patiently pointed out my shortcomings and reminded of the traps that I need to avoid. In this process, I try to learn not only how to improve a study, but also how to foster the mindset of "handling them like a scientist." It is a great blessing for me to study under their supervision.

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APPENDIX A. SEARCH TERMS AND THE FULL LIST OF INCLUDED ARTICLES FOR THE SYSTEMATIC REVIEW

The following is the supplementary data for the systematic literature review in Chapter 2. The data is also available in:

Wen, C., Albert, C., & Von Haaren, C. (2018). The elderly in green spaces: Exploring requirements and preferences concerning nature-based recreation. Sustainable Cities and Society, 38, 582–593. https://doi.org/10.1016/j.scs.2018.01.023

The search terms for each database

Database	Search terms
Web of Science	TS=("old* people" or "old* age" or "old* adult*" or "old* population" or "old* group*" or "aging people" or "aging population" or "population aging" or "elder* people" or "elder* group*" or "elder* age*" or "elder* adult*" or pensioner* or seniors or "senior citizen*") AND TS= (park* or garden* or "green space*" or greenland* or environment* or landscape* or wildness* or natur* or outdoor*) AND TS= (recreation* or tour* or leisur* or entertain* or enjoy* or relax* or pleasure or playable or "fun" or "games") AND TS= (scen* or visual or sight* or smell or sound* or touch or feeling or perception or peiceiv* or safe* or belonging* or creat* or accessibilit* or transport* or facilit* or maintenance or maintain* or cleanness or cultur* or histor* or vegetation* or animal* or character* or quali* or attribute* or feature* or satisf*) NOT TS= (drug* or medicine or pharmacy or food* or spine or brain or surgery or nerve or hydrogen or parkinson or clinic* or toxin* or robot or medical or disaster disorder)
Scopus	TITLE-ABS-KEY ("old* people" OR "old* age" OR "old* adult" OR "old* population" OR "old* group" OR {aging people} OR "aging population" OR "elder* people" OR "elder* group" OR "elder* age" OR "elder* adult" OR "pensioner" OR {seniors} OR "senior citizen") AND title-abs-key= (park OR garden OR {green space} OR greenland OR environment OR landscape OR wildness OR natur* OR outdoor*) AND title-abs-key= (recreation* OR tour* OR leisur* OR entertain* OR enjoy* OR relax* OR pleasure OR playable OR {fun} OR {games} OR excursion) AND title-abs-key= (scen* OR visual OR sight* OR aesthetic OR smell OR sound* OR touch OR feeling OR perception OR peiceiv* OR safe* OR belonging* OR creat* OR access* OR transport* OR facilit* OR maintenance OR maintain* OR clean* OR cultur* OR histor* OR vegetation* OR animal* OR character* OR quali* OR attribute* OR feature* OR satisf*) AND NOT title-abs-key= (drug* OR medicine OR pharmacy OR food* OR spine OR brain OR surgery OR nerve OR hydrogen OR parkinson OR clinic* OR toxin* OR robot OR medical OR disaster OR disorder)

The full list of included articles for the in-depth analysis

No.	Bibliography
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