Ecological Processes

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Nature-based recreation for the elderly in urban areas: assessing opportunities and demand as planning support

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Abstract

Background: With elderly people comprising a growing share of the population, landscape planners need to consider their specific requirements to enhance the opportunities for them to engage in nature-based recreation (NBR). However, few studies have spatially assessed the recreation potential, demand, and opportunities for elderly people in cities. Thus, this paper aimed to spatially model and investigate the NBR opportunities for and demand of elderly people in urban areas. A spatial framework based on the ESTIMAP recreation model was developed, considering special factors to better reflect elderly people's preferences regarding NBR at the city scale. In particular, NBR opportunities were assessed considering landscape aesthetics, various types of facilities, and proximity. The street network was used to understand elderly people's walking behaviours regarding green spaces and related facilities.

Results: A case study in Hannover, Germany, demonstrated the applicability of the proposed method. The results illustrate the spatial heterogeneity of recreation options for the elderly. Only parts of Hannover's green spaces offer high recreation opportunities for elderly people. Many of the existing green spaces lack diverse landscape components and sufficient supply of facilities, resulting in a compromise to aesthetics and recreational opportunities.

Conclusions: The proposed method contributes to research on spatial planning and environmental justice by incorporating vulnerable groups' preferences and needs in spatially assessing NBR. The planning implications highlight pocket gardens and greenways connecting communities and parks as development opportunities in the city.

Keywords: Sustainability, Nature-based recreation, Population aging, Landscape architecture, GIS mapping, Urban design

Introduction

Recent population aging trends have received increasing attention from landscape practitioners, who need to develop elderly-friendly environments to improve their access to and experience on nature-based recreation (NBR) (Alidoust and Bosman 2015; La Rosa et al. 2018; Wen et al. 2018). In many countries, the term "elderly people" refers to the population above the age of 60 or 65 according to the census; the term is also related to retirement and a decline in functional capability (Orimo et al. 2006; Milanović et al. 2013). Elderly people can obtain multiple health benefits including physical fitness, social integration, and stress reduction by undertaking leisure activities in nature, such as walking, relaxing, or playing in green spaces (Lee and Maheswaran 2011; Leaver and Wiseman 2016).

To encourage elderly people to enjoy NBR, planners should reduce environmental barriers to NBR and consider the preferences of elderly people (Loukaitou-Sideris et al. 2016; Wen et al. 2018). Considerable efforts have focused on exploring scientific evidence on elderly people's recreational behaviour and their preferences

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regarding environmental features. Overall, it has been found that elderly people tend to prefer beautiful scenery, safe environments, accessible green spaces, and well-maintained park facilities (Aspinall et al. 2010; Loukaitou-Sideris et al. 2016). However, less attention has been paid to transforming the available evidence into a spatial assessment to inform landscape planners on how NBR opportunities and demand are distributed for elderly people. Although some research has been carried out assessing and mapping recreational opportunities, the results have largely been based on the demand of the general population, and the analytical units are often limited to urban parks (see Sect. "State of knowledge" for details). The lack of city-scale spatial assessment for elderly people may hinder planners in making decisions to improve the supply–demand relationship of NBR for an aging urban population.

Accordingly, the objective of this study was to spatially model elderly people's opportunities and demand for NBR in urban areas. Two research questions are addressed: (1) What potential, opportunities, and demand regarding NBR among elderly people exist in the case study area? (2) To what degree is the demand for NBR among elderly people met? All the abbreviations used in the manuscript are in Table 1.

State of knowledge

Mapping NBR to support planning

Mapping NBR has been attracting growing interest because it can help plan-makers better understand different environmental conditions for NBR in a spatially explicit manner (Casado-Arzuaga et al. 2013; Maes et al. 2015; Cortinovis and Geneletti 2018). Regarding NBR as a type of cultural ecosystem services that people obtain from nature with the help of human inputs (Costanza 2008; Milcu et al. 2013; Burkhard et al. 2014), recent mapping practices have considered the following components in terms of service delivery:

(1) Recreation potential, which represents the state of nature with emphasis on naturalness, biophysical characteristics, and aesthetics related to the plantation (van Zanten et al. 2016; Hermes et al. 2018);
(2) Human inputs associated with green spaces, for example, infrastructure, roads, and facilities (Cortinovis et al. 2018; Peña et al. 2015);
(3) Recreation demand, often indicated by population hotspots, visits, or a proxy of uses (see the review by Wolff et al. 2015); and
(4) Recreation opportunities, obtained by, for example, classifying recreational conditions based on the recreation potential and human inputs using the ESTIMAP model (Paracchini et al. 2014; Baró et al. 2016; Vallecillo et al. 2019; Suárez et al. 2020) or presenting multiple criteria using a tiered approach (Grêt-Regamey et al. 2015).

Considering elderly people in mapping urban NBR

Only a few studies have investigated the spatial patterns of NBR for elderly people at the city scale. In urban settings, mapping NBR often requires detailed data on the local landscape and facilities (Malinga et al. 2015). A recent study in Trento, Italy, mapped the recreational potential and opportunities for elderly people and youth after adapting a localized ESTIMAP model (Cortinovis and Geneletti 2018; Cortinovis et al. 2018). The study used expert scores to tune the model parameters, including scores on natural features, land cover, and facilities, such bus stops, trails, and playgrounds. In another study considering cases in Catania, Italy and Nagoya, Japan, researchers mapped accessibility to categorized urban parks for elderly people and children (La Rosa et al. 2018). The categorization was based on park size, land cover, tree cover, and the presence of certain facilities. The results helped identify key locations to improve green space quantity, quality, and accessibility (La Rosa et al. 2018).

However, assessments still need to consider how to better reflect the preferences and needs of the investigated social groups (Casado-Arzuaga et al. 2013; Haase et al. 2014), such as elderly people. First, existing studies have often applied the same indicators of NBR to study

Table 1 List of abbreviations used in this study

Acronyms	Full name	Notes
NBR	Nature-based recreation	Leisure activities in blue and green spaces, as one type of cultural ecosystem services
ESTIMAP	Ecosystem Services Mapping Tool	A family of models used to spatially assess types of ecosystem services
DLM	Digital landscape model	A source of digital topographical geodata in Germany
LAQ	Landscape Aesthetic Quality model	A modelling framework to spatially assess landscape aesthetics using objectively measured environment features

elderly people and other social groups used for comparison (Kabisch and Haase 2014; La Rosa et al. 2018; Cortinovis and Geneletti 2018). Elderly people, however, may have special preferences and requirements that differ from those of other groups (Loukaitou-Sideris et al. 2016; Wen et al. 2018). Second, in modelling recreation potential, previous studies have usually considered the natural feature or land use of one particular place (Baró et al. 2016; Cortinovis et al. 2018; Vallecillo et al. 2019). People's visual experience of a place can also depend on its surrounding area, in which the diversity of landscape components plays an important role (Hermes et al. 2018). For example, in urban areas, paved squares surrounded by trees are often preferred by elderly people (Alves et al. 2008) but are not reflected in models that only consider land cover. Third, when accounting for the accessibility of natural features and facilities, studies have often applied Euclidian distance that measures straight-line distance (van Riper et al. 2012; Baró et al. 2016; Wüstemann et al. 2017; Cortinovis et al. 2018). Using Euclidian distance is intuitive and generally suitable in many contexts, but the resulting measured distance is likely to be overestimated compared to the network distance within the city network (Zhang et al. 2011). Elderly people's walking behaviours should be better considered when assessing their NBR in urban settings, where road networks cannot be overlooked.

Therefore, this study attempted to develop a special version of the ESTIMAP recreation model (Zulian et al. 2013; Paracchini et al. 2014; Cortinovis et al. 2018) applicable to elderly people. It was developed by reference to a previous study—a systematic literature review of elderly people's needs and preferences regarding NBR (Wen et al. 2018; Wen 2019). In particular, the city of Hannover in Germany was used as a case to investigate recreation potential, opportunities, and demand for elderly people. Hannover is a typical Germany city with a population of half a million. A previous study in Hannover confirmed that the elderly population is not at a disadvantage of unequal access to urban green spaces, although the study called for the creation of an analytical framework to perform an in-depth spatially explicit evaluation of NBR suitability for elderly people (Wen et al. 2020). In this regard, the methods and results of this study can help generate planning suggestions to support efforts to develop elderly-friendly environments.

Methodology

Study area and its typicality

This research considered Hannover, Germany, as the study area. The percentage of elderly people (over 65) in the city was 18.8% in 2017, and it is expected to increase to 21.9% by 2030 (Landeshauptstadt Hannover 2017). The demographic characteristics of Hannover are similar to those of many major cities in Germany, each of which accommodates 400,000 to 600,000 residents (Statistisches Bundesamt 2016). Many communities with a high number of elderly people are located on the outskirts of the city (Figs. 1, 2). Hannover is famous for its exhibition industry, liveable environments with large green spaces, and label as a low-stress "green city" (see the news report by O'Hare 2017). The city's main green spaces include a few medium-sized urban parks near the city centre as well as urban forests near the eastern boundary (Figs. 3, 4).

General framework and data collection

This study developed a spatial model based on the ESTIMAP recreation model. The ESTIMAP model is a flexible framework that can be used to spatially assess various ecosystem services, including NBR (Zulian et al. 2013; Paracchini et al. 2014). The framework accounts for recreation opportunities by cross-tabulating or overlaying a variety of classified thematic maps (Cortinovis et al. 2018). The key thematic maps of the model usually include a recreation potential map, a proximity map, and a demand map (Zulian et al. 2013; Paracchini et al. 2014; Baró et al. 2016). Each thematic map can be composed of different indicators that reflect particular research interests (Carvalho et al. 2017). For the purpose of studying elderly people, we followed a recommended protocol (Table 2) to adapt the original ESTIMAP model (Carvalho et al. 2017) for our special use, and we selected proper map production process, spatial and temporal scale, and model rules.

Next, a framework of factors to assess NBR potential, opportunities, and demand for elderly people was proposed (Fig. 5). The selection of factors was based on a systematic literature review summarizing elderly people's preferences for NBR (Wen et al. 2018). The datasets are from multiple sources and are elaborated on in Table 3.

Methods for assessing NBR components

Assessing NBR potential

NBR potential was conceptualized by adapting a landscape aesthetic quality (LAQ) model that was created considering the German context (Hermes et al. 2018). The original LAQ model applied a multi-layered approach to study the aesthetic quality at the national scale (Hermes et al. 2018). Landscape aesthetics often play a dominant role in affecting elderly people's NBR, and, compared to the general population, the elderly may have a stronger visual preference for diverse plants, predictable environments, and distinctive features (Mitchell et al. 2004; Jorgensen and Anthopoulou 2007; Alves et al. 2008; Aspinall et al. 2010; Wen et al. 2018). This study

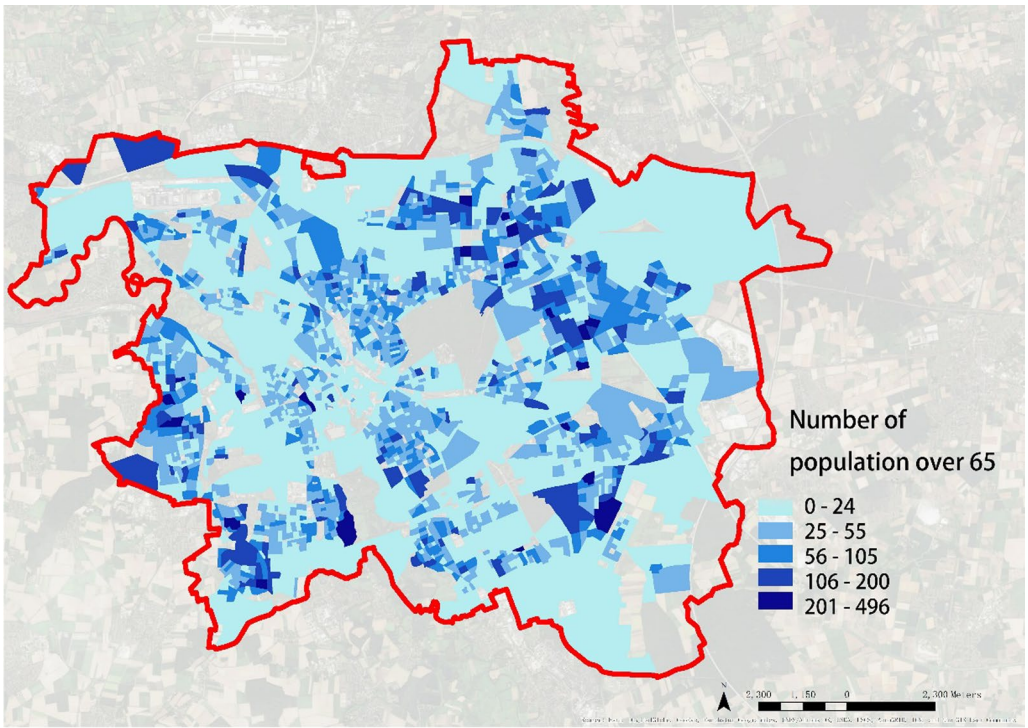

Fig. 1 Distribution of elderly people over the age of 65 in Hannover at the census block level (source: The City of Hannover)

adjusted the factors and parameters of the model to study elderly people at the city scale. The following three factors were included:

1. Average landscape aesthetic value in the surrounding environment. We applied a raster-based moving-window approach to calculate the average aesthetic value of a place considering its landscape components and surrounding areas (for technical details also see Wen 2019). This approach was similar to a focal analysis of landscape metrics, originally developed for modelling the landscape aesthetics in German context using objectively measured landscape features. The aesthetic score for each type of landscape component was prepared based on existing studies in local German contexts (Nohl 2001; Haaren and Hülsbergen 2008; Boll et al. 2014a, b) (Additional file 1: Appendix A). In reference to the previously cited field studies, the landscape components in this study included the type of natural ecosystem (biotope), constituted by a variety of habitats with similar physical features and landscape functions. It should be noted that the referenced aesthetic value scores were sourced not only from elderly respondents but also from other age groups (see Boll et al. 2014a, b; Nohl 2001). This could constitute a limitation of this study. However, there has been no field survey specifically addressing elderly people's landscape aesthetic scores in the study area, and the referenced source was the best-available relevant dataset for the development of an indicator-based assessment.
2. Landscape diversity in the surrounding environment: the landscape diversity of an area was calculated by the Shannon diversity index (SHDI). For this context, a high value indicates a more diverse environment in which landscape types are equally abundant. The formula for the SHDI is as follows:

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

Here, m is the number of landscape component types in the given area, and P_i is the area proportion of type i in the given area.
3. Landscape rareness value: this value indicates whether a particular landscape component in the study area is rare. This study applied an approach similar to the original model measuring rareness using a threshold of area proportion (Hermes et al. 2018). Here, rareness was defined according to whether a type of landscape component belonged to one of the rarest types, whose combined areas covered 5% or less of the total study area. The influence

Fig. 2 Administrative division in the city of Hannover. There are 13 main districts in the city (source: official website of the city www.hannover.de)

of the rare areas was determined based on the following distance decay effect function (Zulian et al. 2013):

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

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

For the final scoring of landscape aesthetics, the three factors above were summed and normalized between 0 (worst aesthetics) and 1 (best aesthetics), using the same approach as previously used for the ESTIMAP model (Zulian et al. 2013; Paracchini et al. 2014).

Assessing human inputs

Human inputs refer to the necessary facilities and infrastructure that help people to access and enjoy the benefits provided by nature (Burkhard et al. 2014; Albert et al. 2016). This study categorized human inputs for NBR among elderly people as being facility- and proximity-related (Wen et al. 2018).

The facility-related inputs consisted of four factors: green space maintenance, toilets, exercise facilities, and corner shops. The selection of these factors was based on scientific evidence that elderly people prefer green spaces: (1) near toilets and small business settings (e.g., corner shops) for convenience; (2) with regular maintenance for safety considerations, and (3) equipped with outdoor exercise facilities and leisure fields for physical activity (Loukaitou-Sideris et al. 2016; Wen et al. 2018).

The impact scope of the facilities was measured by network distance. This research referenced walking distances from studies of short-trip leisure and elderly people's walking behaviour (Kaczynski et al. 2008; Grunewald et al. 2017), and the maximum walking distance to facilities was set to 500 m. A distance-decay effect was considered so that closer facilities received a higher score.

The proximity-related inputs consisted of two factors: proximity to local roads and to residential buildings or nursing homes. After the two proximity factors were computed and reclassified in GIS, the cross-tabulation approach was applied to combine the two maps, identifying areas that were close to residential

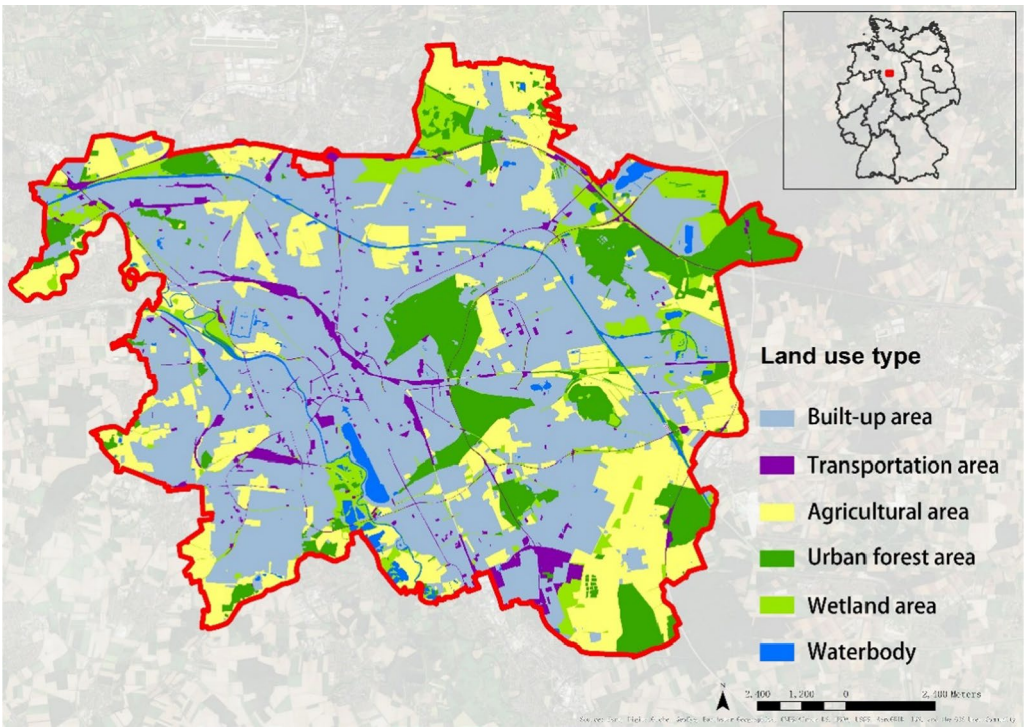

Fig. 3 Land use classification in the city of Hannover. There are several large urban forests in the city and a few wetlands scattered near the city boundary (source: DLM Region Hannover)

Fig. 4 Typical places for people to enjoy nature-based recreation (NBR) in Hannover. The top-left photo shows an urban forest. The bottom-left photo shows a street garden in the residential area. The right photo shows a linear greenway in the western part of the city

Table 2 Protocol to adapt the ESTIMAP recreation model for the special use in this study

Step	Key questions	Consideration
Type of knowledge production	• What is the application of the final map?	The final assessment maps 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 are stakeholders involved?	Designing the model considering literature, demographic reports, and local plans related to elderly people
Spatial and temporal scale	• What temporal and spatial scales are considered?	The model concerns the biophysical conditions of nature and human inputs at the city scale. The model is expected to be representative in the near future due to consistent urban renewal and demographic changes
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, and (2) whether data are available at the city scale
	• How can we combine these components?	The model needs to include both the "overlay" approach and "advanced look-up 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?	Several input map layers can be validated by multi-source datasets, especially for the physical environmental features. For example, landscape components and certain facilities can be acquired from other data sources, such as satellite images. However, the maps of landscape aesthetics and opportunities are yet to be verified. So far, there have been no field studies investigating recreation opportunities for elderly people in the study area. Although conducting a spatially explicit field survey across the region is beyond the scope of this modelling study, future participatory works (e.g., Public Participatory Geographic Information Systems—PPGIS) can be used to validate and refine the results

The protocol refines the spatial modelling process by underscoring the importance of local conditions, research purposes, and effectiveness of the analysis

The protocol is referenced to Carvalho et al. 2017

buildings or nursing homes (Vallecillo et al. 2019). Cross-tabulation is commonly used to analyse how different categories of data combine, and it reveals how one variable is distributed across different levels of another variable.

Additionally, this study considered safety-related issues using objectively measured traffic data and crime statistics. Since the best-available datasets are sparse in resolution and not age-sensitive, this case study does not incorporate them in the final model. However, the selection of human-input factors outlined above was able to partially represent elderly people's safety perception. For example, proximity to home and presence of corner shops are associated with familiarity, having eyes on the street, and a sense of safety, as indicated by the classic *The Death and Life of Great American Cities* and other literature (Jacobs 1961; Wright Wendel et al. 2012).

Assessing NBR opportunities

The NBR opportunities were assessed by cross-tabulating the NBR potential and human inputs. The areas with a high value regarding NBR opportunities were considered suitable for NBR among elderly people as they were aesthetically pleasing, accessible, and had convenient access to supporting facilities. This approach follows a previous study (Wen et al. 2018), which indicated that elderly people tend to consider opportunities for visiting green spaces based on a combination of positive conditions.

Hotspot analysis of NBR opportunities

We spatially identified areas with either high or low-value clusters by applying a hotspot analysis using the Getis-Ord Gi* statistic. The hotspot analysis computed a statistic on the local spatial autocorrelation for each location within the study area. It also explored significant clusters against a spatially random process. The results of

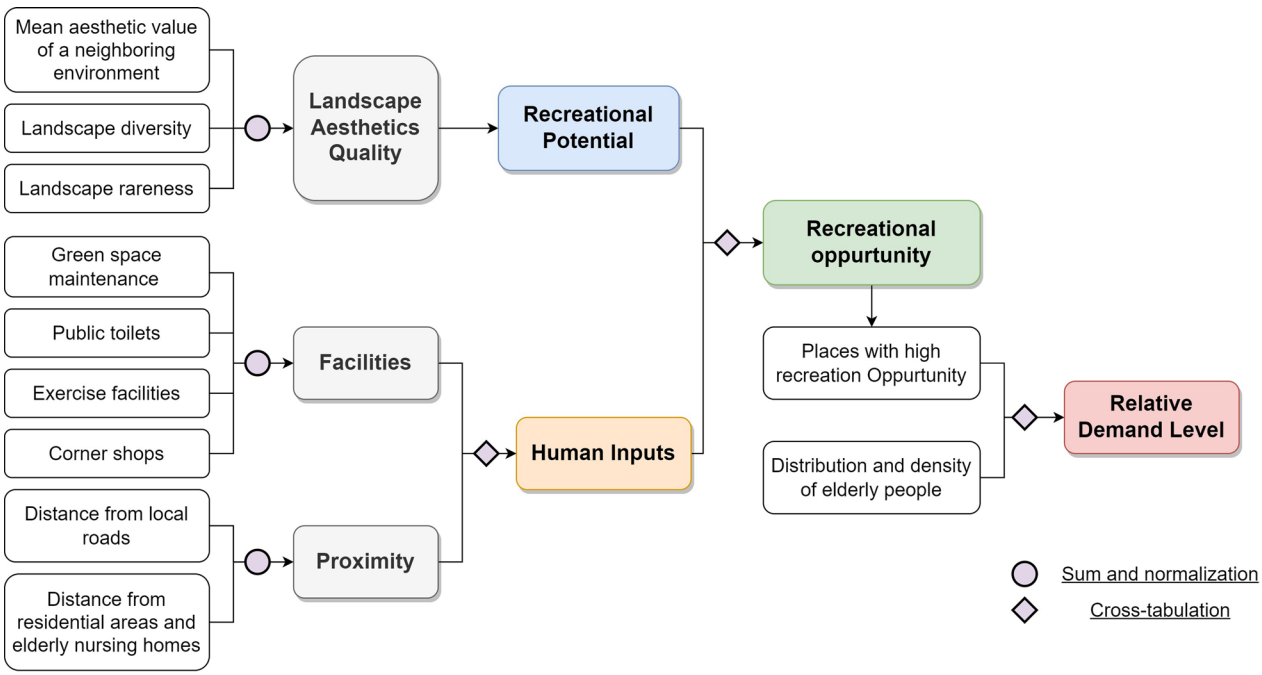

Fig. 5 Flowchart for assessing the recreational potential, opportunities, and relative demand for NBR among elderly people. Following the ESTIMAP model's rule, this study applies either sum-and-normalization or cross-tabulation to analyse the relationship between different variables

hot- and cold-spot helped obtain a better understanding of patterns of NBR opportunities at the city scale.

Assessing NBR demand

The relative NBR demand level was calculated based on a cross-tabulation of the elderly population density and their proximity to the areas with the most NBR opportunities. This is not arguing that the remaining urban green spaces cannot attract elderly people, although the areas with the highest NBR opportunities scores have positive landscape aesthetics, social convenience, and proximity at the same time.

To implement this approach, the distribution of elderly people was calculated in detail based on population grids at the 100-m scale, along with the demographic statistics from each block's census (Landeshauptstadt Hannover 2017). Each grid was used to calculate the Euclidian distance to the nearest area with the highest recreation opportunities. Despite that the study applied network distance to study the proximity of human inputs, there were two main reasons for using a straight-line distance to measure the accessibility here. In urban contexts, detours are worth considering in evaluating accessibility via network distance, but the route will only be accurate when the origin and destination are explicit, such as from the home address to a park entrance or a facility. One feature of this study is that it aimed to evaluate the continuous recreation opportunities across the whole city, where the high potential places are often urban blue and green spaces or even informal landscapes without explicit main entrances. Furthermore, the Euclidian approach can be better generalized across different urban settings especially when detailed data on pedestrians at the street level are unavailable.

Next, the classified distance was cross-tabulated with the elderly population density, resulting in the demand level (Table 4) (Zulian et al. 2013; Baró et al. 2016). The units for demand level were dimensionless, and the values were used to demonstrate the relative extent to which each block was densely populated and far away from NBR opportunities (Baró et al. 2016). Finally, the unsatisfied demand indicated the density of the elderly population in areas beyond walking distance to the nearest areas with high recreational opportunities (for the choice of distance parameters see Sect. Assessing human inputs).

Results

Spatial patterns of NBR potential, human inputs, and opportunities

The landscape aesthetic quality (LAQ) model revealed an uneven distribution of recreation potential in Hannover (Fig. 6, top). While the built areas covering more than half of the city offer low recreation potential, we found that areas with high potential were located near the

Table 3 Model components, configuration, and data used to study recreation opportunities

Component	Relevant question	Model configuration				
		Model used	**Variable(s)**	**Number of variables**	**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 the surrounding environment: calculated by focal statistics for each cell, indicating the average aesthetic value from the cell's surrounding areas Landscape diversity value: the 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 was adapted from a recent study in the German contexts (Hermes et al. 2018). To better understand elderly people's visual experience in urban areas, we used a local fine-scaled biotope dataset and adjusted the extent of the surrounding environment to 100 m
Human inputs	To what degree are the supporting facilities available in different locations of the city?	Facilities	Green space maintenance: an index to determine whether the biotope of a place belongs to leisure and sports fields, historical sites, or graveyards. It assumes these types of green spaces receive frequent maintenance and are therefore 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	The environmental features were selected based on existing evidence of elderly people's preferences for NBR. The affected areas of these facilities were adjusted by distances that reflect elderly people's behaviour in terms of walking for leisure in urban settings
	How accessible are the areas from residential areas, nursing homes, and roads?	Proximity	The proximity of local roads The proximity of residential areas and nursing homes	2	HGW OSM	Detailed information on local roads, residential buildings, and nursing homes were 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

boundaries. These areas included wetlands and lakes in the south, royal gardens in the west, and urban forests in the northeast. By contrast, the areas with low recreation potential were the densely populated districts near the city centre and the agricultural land. Notably, only small parts of the large urban parks were found to have high potential for elderly people.

Table 4 The relative demand level for NBR among elderly people

		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 demand level of each analytical unit is determined by the cross-tabulation of (1) the elderly people density and (2) the distance to the nearest high recreation opportunity places

The approach was derived from Baró et al. (2016) and Paracchini et al. (2014)

In contrast to recreation potential, the assessment of human inputs shows that the areas with the best human inputs were located the city centre, spreading several kilometres outside the centre (Fig. 6, bottom). Although areas near the eastern boundary had high recreation potential, few of the investigated facilities were present there.

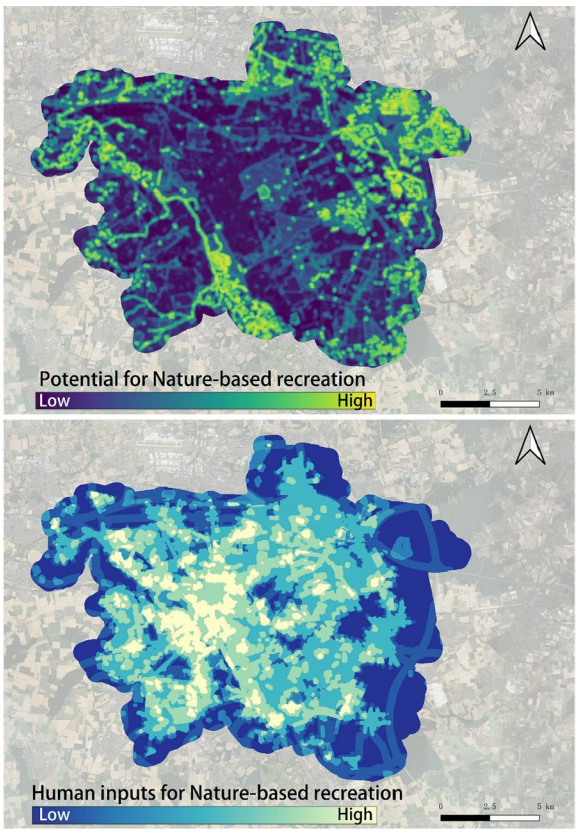

Fig. 6 NBR potential and human inputs for elderly people. The top subgraph shows the NBR potential. The value is normalized to the 0–1 range, where 0 indicates the lowest potential and 1 the highest potential. The bottom subgraph shows the human-input value, which is ranked based on a cross-tabulation of the facility- and proximity-related inputs. The colour ramp shows the range from the lowest (dark) to the highest (light) human inputs

Figure 7 shows the spatial patterns of NBR opportunities for elderly people in Hannover. The places with high opportunities met the two requirements at the same time: They had aesthetic quality as well as good human inputs. The results revealed two key linear patterns representing areas with high recreation opportunities (Fig. 7), either along lakesides or as urban greenway corridors. A few other small areas with high recreation opportunities were scattered throughout the city. These could indicate street gardens suitable for elderly people's NBR.

Table 5 summarizes the average recreation opportunities value for the whole city and each district. The average value for the whole city is 4.3 (on the 1–9 scale). From the table, we can identify districts that had a large share of elderly people (> 20%) but whose value of recreation opportunities was below the average. These districts included Buchholz-Kleefeld and Kirchrode-Bemerode-Wülferode.

Hotspot analysis of NBR opportunities

The *z* scores from the Gi* statistic demonstrate the clusters of the relatively high and low recreation opportunity values (Fig. 8). Based on the results, several linear corridors were identified as high NBR opportunity clusters, representing the linkages between rivers, wetlands, and green spaces of diverse landscape components. The cold spots were found to be mainly in large monotonous agriculture and built areas.

Spatial pattern of NBR demand among the elderly

The distribution of demand is summarized in Fig. 9, considering the density of the elderly population in each population grid and its distance to the nearest high-opportunity areas (see Table 4 for cross-tabulation). The areas with the highest demand were mainly located within a strip of land running across the city centre. These areas are densely populated by elderly people and

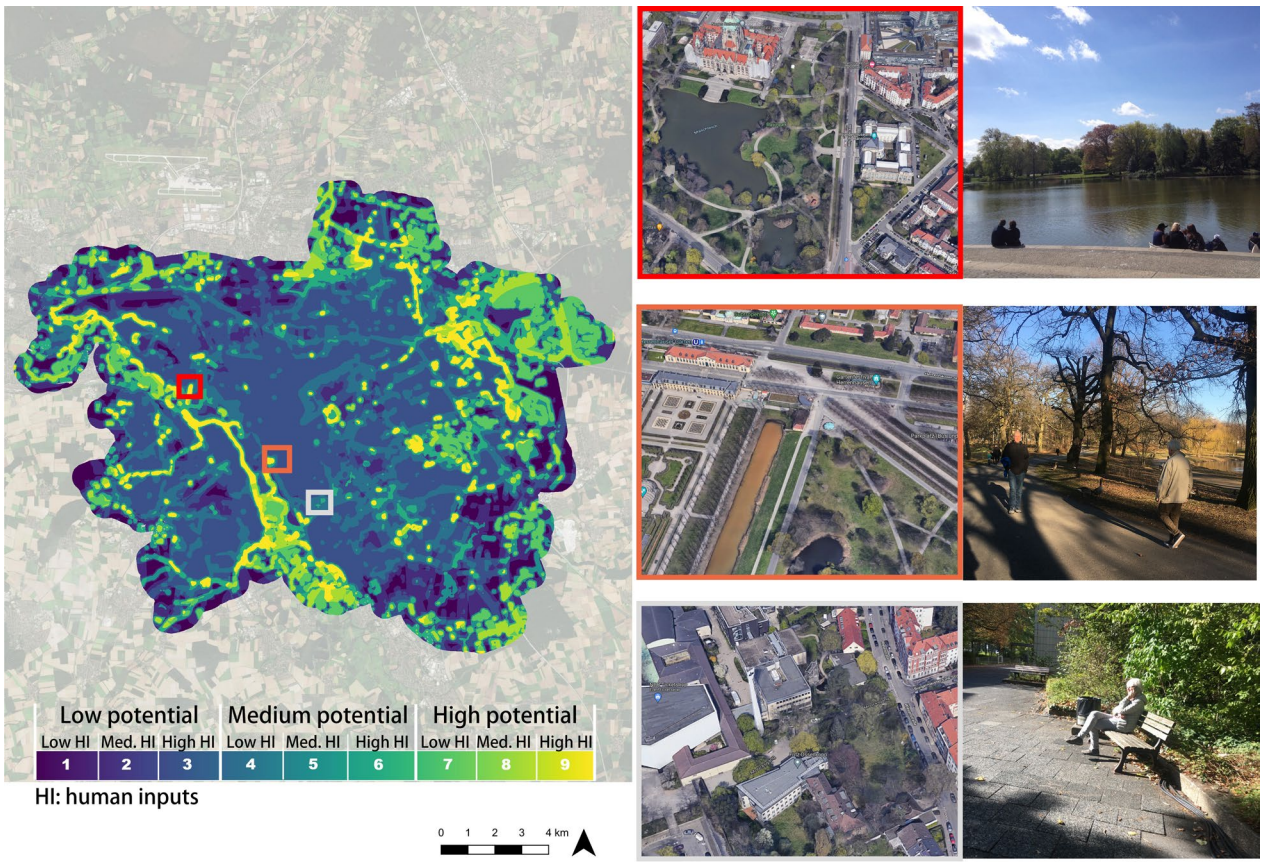

Fig. 7 NBR opportunities for elderly people. The left subgraph shows that the value of NBR opportunities is ranked to nine classes based on a cross-tabulation of NBR potential and human inputs. The map shows the range from the lowest opportunities (dark) to the highest (light). The right subgraph shows three sample sites, each of them demonstrating a 3D image from Google Map and a photo taken by the authors. The three sample sites represent typical places with high opportunities in the city

are often beyond a short walking distance to high-opportunity locations.

Discussion

Insights for the spatial understanding of elderly people's NBR

Our study provides a spatial representation of elderly people's NBR at the city scale. On the one hand, it inherited the advantage of a modular structure from ESTIMAP, making it convenient to implement different preference factors. On the other hand, by incorporating a tested aesthetic module (LAQ) and a network-based analysis of elderly-concerned factors, the study reflects elderly people's behaviour and preferences in cities.

As a novel contribution, the continuous mapping results across the city advance the understanding of general NBR opportunities and demand, contrasting with the commonly used results based on certain statistical units (gardens or parks). Results that depend on a statistical unit can be risky to ignore the spatial heterogeneity inside the unit. For example, when we aggregate the continuous mapping results (as in Fig. 7) into the district-based summary table (as in Table 5), information loss can emerge, preventing planers from understanding the variation of spatial experience regarding NBR. The results from different observational units may remind practitioners of the modifiable areal unit problem. In particular, the choice of an observational unit may have an impact on understanding the supply–demand mismatch, subsequently affecting planning (Tan et al. 2019). Therefore, a spatially explicit assessment can complement the tubular statistics to inform practitioners of plan development.

This research demonstrates a spatially explicit method to support landscape development based on the consideration of special target groups. The study used indicators as a proxy to quantify NBR for elderly people. Indicators are an alternative to actual data on people's behaviours during short-trip recreation, which are usually unavailable (Boll et al. 2014b), especially for vulnerable groups, such as elderly people. Two recent studies

Table 5 Zonal statistics of the 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	37,254	14.2	0.24	3.9	10.7
2	Vahrenwald-List	70,720	16.6	0.12	3.3	8.2
3	Bothfeld-Vahrenheide	49,667	22.4	0.36	4.6	30.7
4	Buchholz-Kleefeld	45,241	22.6	0.23	3.9	14.0
5	Misburg-Anderten	33,545	21.8	0.46	5.1	28.2
6	Kirchrode-Bemerode-Wülferode	32,069	21.4	0.25	3.9	23.8
7	Südstadt-Bult	43,119	16.8	0.28	3.6	7.1
8	Döhren-Wülfel	34,512	20.8	0.33	4.2	16.5
9	Ricklingen	46,048	21.6	0.21	4.3	14.7
10	Linden-Limmer	45,725	12.2	0.30	4.1	8.2
11	Ahlem-Badenstedt-Davenstedt	34,467	22.3	0.19	4.3	9.9
12	Herrenhausen-Stöcken	36,859	19.1	0.28	4.4	12.2
13	Nord	32,435	13.3	0.30	3.7	10.9
	City of Hannover	541,661	18.7	0.32	4.3	204

The highest opportunities have the value 9 in the opportunity map

The population data are from the City of Hannover in 2018. For a detailed evaluation of equality in access considering elderly people's mobility, see Wen et al. (2020)

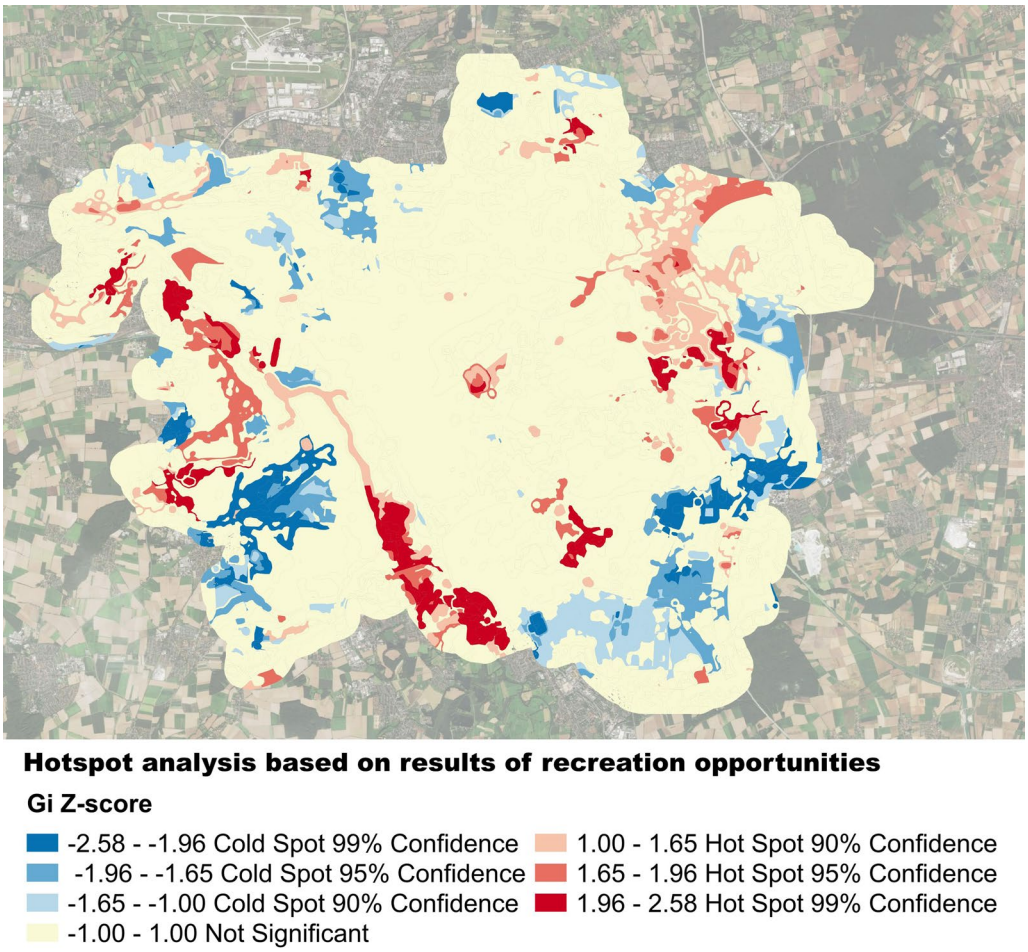

Fig. 8 Hotspot analysis based on the results on NBR opportunities for elderly people. The calculated *z*-score indicates how many standard deviations the value differs from the mean

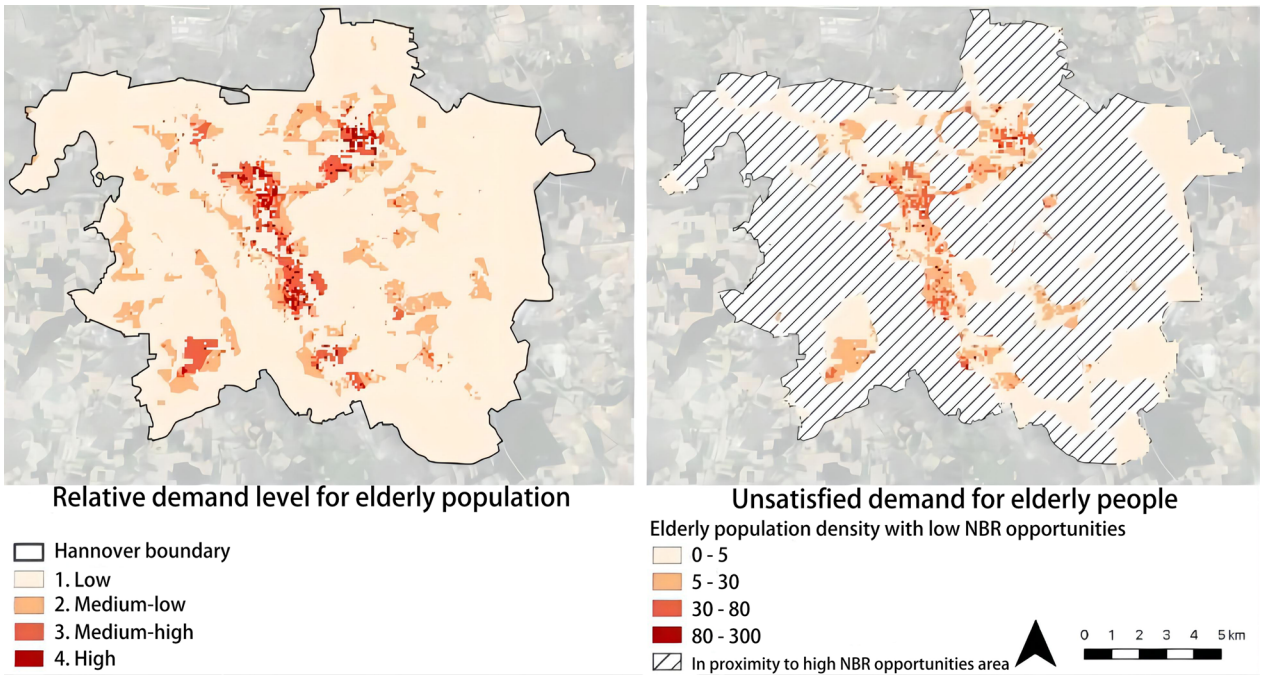

Fig. 9 The modelling results for NBR demand. The left subgraph shows the relative demand level for elderly people, which is determined by the cross-tabulation of elderly population density and the distance the nearest places with high recreational opportunities. The right subgraph shows the unsatisfied demand among the elderly population, indicating the density of the elderly population in areas beyond walking distance to the nearest areas with high recreational opportunities

have also used indicators to assess NBR related to elderly groups, although they focus more on accessibility (La Rosa et al. 2018) and planning scenarios for redeveloping brownfields (Cortinovis et al. 2018), respectively. As comparison, this research advances the spatial understanding of elderly people's NBR by implementing a framework of factors able to reflect their preferences based on systematic reviews (Loukaitou-Sideris et al. 2016; Wen et al. 2018). The spatial assessments were conducted not only for NBR opportunities, but also for NBR potential and the relevant facilities. Accordingly, the relationship among these factors was analysed in light of landscape planning and facility management. Our method confirmed that the spatial distribution of NBR potential and human inputs often did not overlap, revealing that elderly people who are sensitive to supporting facilities may lose the opportunity to visit natural and aesthetically pleasing places. This indicator-based spatial assessment of NBR can complement the survey-based research to provide a map representation of the present state of NBR for elderly people.

As expected, this method addressing vulnerable groups led to lower scores on NBR opportunities, compared to other mapping studies on NBR using the ESTIMAP method (e.g., Cortinovis et al., 2018). These differences are comprehensible based on two reasons. First, the study applied an LAQ module that addresses human visual experience based on a particular extent of view (Hermes et al. 2018). This approach addresses not only the landscape component, but also the diversity in their combination. Many urban environments and green spaces were thus identified as lacking diversity in landscape components, leading to low scores on aesthetic value and

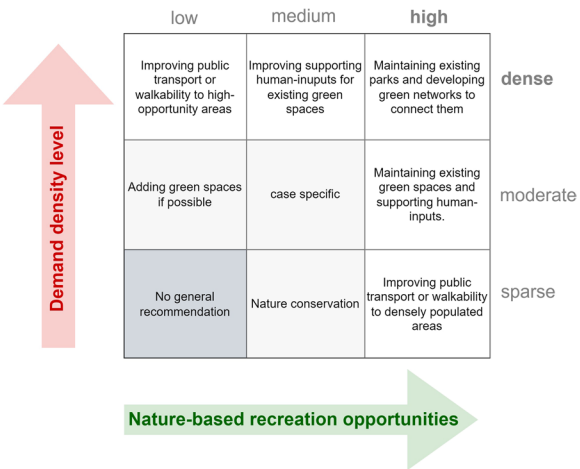

Fig. 10 General planning recommendations based on the relationship between NBR opportunities and demand density level. The recommendations are based on the cross-tabulation of different levels of demand density and NBR opportunities

opportunities. This result confirmed previous findings showing that many urban ecosystems are at risk of being visually homogeneous as a result of being flat and homogeneous (Peña et al. 2015). Second, this study selected factors for human inputs demonstrated as crucial for short-trip NBR among elderly people. Lacking the facilities might decrease the attraction of a green space for the elderly, although this may not be true for other groups.

In the case of Hannover, our method confirmed that the spatial distribution of natural potential and human inputs were not overlapped, revealing that existing natural and aesthetically pleasing places do not reach their potential due to a lack of supporting facilities. The distribution of NBR opportunities resonates with evidence that many dense residential places near urban centre are beyond a distance threshold regarding high recreational opportunities (see the discussions of distance in Grunewald et al. 2017 and Kaczynski et al. 2008). The modelled spatial relationship between opportunities and demand can be used to deduce various planning strategies, such as adding small green spaces in key positions, improving supporting facilities, or enhancing accessibility (La Rosa et al. 2018).

Although this study explored elderly people's preferences, the proposed modular framework could be used to analyse other social groups (e.g., children). For example, the LAQ module for visual experiences and the network analysis for human inputs are flexible and can be implemented with different parameters and factors. For relevant studies of a target group's preferences and needs, the framework can also help to analyse the spatial representation of NBR for that group by considering the preferred landscape characteristics and facilities.

Planning implications

In urban areas, the spatial relationship between NPR opportunities and demand can help planners deduce planning suggestions to improve NBR for elderly people based on different situations (Fig. 10). Planning recommendations may include enhancing supporting human inputs, adding pocket gardens at key positions, or developing green networks to connect scattered high-opportunity areas.

In Hannover's case, the following three main planning suggestions can be made to improve elderly people's NBR:

1. In the city centre, although new large green spaces are challenging to add, planners can improve the quality of existing community gardens by improving the supporting facilities and inserting more pocket parks. These pocket parks will be able to support rest and leisure among elderly people if they are well-designed and have diverse natural features, shades, and seats (Nordh and Østby 2013; Wen et al. 2018).
2. Practitioners should improve walking paths to connect parks and residential areas, especially greenways and riverside walkways. High-quality walking paths can ease travel difficulties and encourage the elderly to visit green spaces (Joseph and Zimring 2007; Cerin et al. 2013a; Zhai and Baran 2016). Recent studies on NBR for elderly people highlighted the importance of walkways mitigating the distributional inequality of green spaces (Cerin et al. 2013b; Zhai and Baran 2016; Artmann et al. 2017).
3. Natural and aesthetically pleasing urban wild can be enhanced by adding the necessary supporting facilities and improving its accessibility from densely populated areas.

Limitations of the study

First, in applying the landscape aesthetic quality model, this study referenced a "look-up table" to score each landscape component in its local context (Additional file 1: Appendix A). The referenced aesthetic values were not derived only from elderly respondents. However, there has been no field survey specifically addressing landscape aesthetic scores from elderly people in the study area, and the referenced source was the best-available relevant dataset so far. Conducting a systematic survey on elderly people's visual preferences was beyond the scope of this study. To partially overcome that, we calibrated the model parameters to reflect elderly people's visual experience in urban settings based on a systematic review of elderly people's needs. Second, a set of distance thresholds was established in analysing the proximity and accessibility of facilities. This study mainly focused on elderly people's short-trip recreation on foot, but some elderly people may consider other transport modes. Different distance parameters might lead to uncertainty or inconsistent results (Kwan 2012; Wang and Wen 2017). Third, to inform local planning practices, this study applied fine-scaled local datasets and did not test generally available data as inputs.

Conclusions

The present study constructed a framework to map NBR opportunities for elderly people at the city scale after adapting the ESTIMAP recreation model. Our model reflected elderly people's preferences by considering landscape aesthetics, various types of facilities, and proximity. The proposed method is intended to support plan-making by providing a spatially explicit evaluation. Case study results in Hannover illustrated

the spatial heterogeneity of actual recreation options for the elderly and the mismatches between NBR opportunities and demand. In particular, the residential areas where most elderly residents live are often beyond walking distance to the nearest areas with high recreation opportunities. The findings also revealed that existing green spaces often lack diverse landscape components and the support of facilities, resulting in compromises on aesthetics and opportunities for elderly people. For planning implications, this study highlighted pocket gardens and greenways that connect different communities and parks (Nordh and Østby 2013; Wen et al. 2018). The proposed method contributes to incorporating vulnerable groups' preferences and needs in spatially assessing NBR opportunities and demand, and it can facilitate planning for environmental justice. If proper indicators for other social groups can be developed, the method can further help planners understand their needs and demand in a spatially explicit manner and then respond.

Abbreviations

NBR: Nature-based recreation; ESTIMAP: Ecosystem Services Mapping Tools; LAQ: Landscape aesthetic quality model; DLM: Digital landscape model, a source of digital topographical geodata in Germany.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13717-022-00390-0.

Additional file 1. Appendix A. The aesthetic scores used for each type of biotopes. The values were prepared by referencing existing studies in scoring landscape aesthetics in Germany, in the research project MANUELA (Boll et al., 2014a, 2014b; Haaren and Hülsbergen 2008; Nohl 2001).

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Author contributions

CW: conceptualization, methodology, software, writing- original draft preparation, writing—reviewing and editing. CA: supervision, conceptualization, methodology, writing—reviewing and editing. CVH: supervision, conceptualization, methodology, writing—reviewing and editing. All authors read and approved the final manuscript.

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Availability of data and materials

The information of "Availability of data and materials" is elaborated in the Sect. "Study area and its typicality" of this article. Parts of the data used for GIS modeling are from the third party and are authorized by the university.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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