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Research Article

Approach to user group-specific assessment of urban green spaces for a more equitable supply exemplified by the elderly population

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Abstract

The use of urban green spaces (UGS) depends on its quality, which is perceived very differently by diverse socio-demographic groups. In particular, elderly people have special demands on the UGS quality. It is essential to know these demands to create an equitable UGS supply. We present an approach to determining some qualitative aspects and the supply of cultural ecosystem services of diverse forms of UGS. This is realised by combining user demands with actual UGS features. In a concrete example, we assessed the UGS quality and supply for both the general population and the subset of elderly people. For the latter group, the activities of relaxing and observing nature, as well as the UGS feature of benches, were found to be significantly more important than for the general population. Nevertheless, this had only a minor impact on the assessed aspects of UGS quality and supply, with little differences detected between the two groups. In Dresden (Germany), we determined that almost half of the elderly population are not provided with high-quality UGS. In these areas, urban planning must increase the UGS quality while taking user demands into account to ensure just access to the positive benefits of UGS for the elderly.

Keywords

accessibility, urban green spaces, user demand, green space quality, green space planning, cultural ecosystem services

Introduction

All around the world, societies are ageing, i.e. the proportion of elderly people is increasing (United Nations, Department of Economics and Social Affairs, Population Division 2020). As is apparent in Europe, the trend is particularly marked in Germany (Statistisches Bundesamt 2016): in 1975, approximately 15% of the country's population was over 65 years old; by 2015, the figure had risen to around 21%, a development set to continue over the coming decades (ibid.).

Although the health of the elderly has generally improved over the past few decades (Crimmins 2004), there is no doubt that the risk of developing physical problems and disease increases with age (Robert Koch-Institut 2015). Cardiovascular disease, impaired hearing and vision, chronic lung disease, diabetes mellitus and geriatric syndromes are the most common ailments (World Health Organization 2018). In addition to these health problems, elderly people are also less resistant to negative environmental impacts in urban settings, such as excessive heat, which can be an additional burden on their health (Arnberger et al. 2017). For this reason, elderly people can be considered a particularly vulnerable population group (Kabisch and Kraemer 2020, Sikorska et al. 2020).

Urban green spaces (UGS) provide multiple ecosystem services for local residents, thereby increasing their quality of life (Bolund and Hunhammar 1999). Access to UGS can help safeguard and improve human well-being (Tost et al. 2019, Hu et al. 2020) and can even reduce the probability of contracting certain diseases (Kabisch et al. 2017). Many studies have confirmed the manifold positive effects of UGS on the well-being of city dwellers (Dickinson and Hobbs 2017). For example, Alcock et al. (2014) found significantly improved mental health in people who moved to greener urban areas, while Kabisch et al. (2021) detected significant drops in the systolic blood pressure of subjects spending time in an old, tree-lined park. More generally, in their literature review on the impact of UGS on human health, Kondo et al. (2018) found that exposure to UGS helped lower mortality rates of local citizens, for example, from cardiovascular disease, as well as decreasing their heart rate and improving their mood. These positive effects can largely be attributed to sporting and leisure activities that take place in UGS, as well as the opportunity UGS offer for relaxation from the stresses of everyday life and its function as a meeting place (Lee et al. 2015). This usability of UGS for improved well-being represents an important part of cultural ecosystem services (Ko and Son 2018).

Such positive effects of UGS on health are one of the reasons why Goal 11.7 of the UN's Sustainable Development Goals calls for '…universal access to safe, inclusive and accessible, green and public spaces, in particular for […] older persons…' (United Nations 2020). With its 'Global strategy and action plan on ageing and health', the World Health

Organization (WHO) goes into even more detail, pointing out that to ensure good health for the elderly, it is important to develop age-friendly environments, including UGS. Further, in order to create such age-friendly environments, it is first necessary to consider the needs of the elderly (World Health Organization 2017). In their current state, it is clear that not all UGS can be accessed and used by elderly people. First, certain criteria which influences the level of usage must be met (Wolch et al. 2014), which also effects the amount of ecosystem services provided by UGS. Such criteria can be identified by considering the specific needs of the elderly. Several studies have already dealt with this topic, employing different methods to determine which criteria are applied by elderly people when visiting UGS (Arnberger et al. 2017) and how this influences the capacity to provide ecosystem services (Giedych and Maksymiuk 2017). In a study conducted in Vienna, elderly respondents were shown images of fictitious UGS with different features and characteristics. By selecting a site, they indicated their preference for the depicted features or characteristics. The most important features were found to be the distance to the site, the availability of shade and water elements, as well as cool temperatures (Arnberger et al. 2017). In another study, managers of retirement homes were asked to name those elements of their facility gardens they consider age-friendly. Almost 80% of the respondents named barrier-free access to the gardens as the most essential feature. In the case of UGS near retirement homes, the lack of toilets and benches, as well as long distances between benches, were particularly criticised (Artmann et al. 2017). The presence of such amenities increases the attraction of UGS for elderly users (Subramanian and Jana 2018).

Other studies have not only assessed the needs of the elderly, but also shown which criteria influence the use of UGS. Concerning needs, many scholars have merely examined the opportunity for recreational walking (Wen et al. 2018). For example, the study by Zhai and Baran (2017) investigated which criteria can encourage elderly people to make use of paths in UGS. Yet such a narrow view can lead to a rather unbalanced development of UGS, with the focus too strongly placed on facilities and equipment (in this case, for walking). While natural elements and subjective perceptions also play a decisive role in the evaluation of UGS, few studies have addressed the context of use and the relevance of such natural/subjective factors for this use. To make fact-based recommendations to UGS planners, it is necessary to gain information not only on the importance placed on a particular UGS feature, but also the number of times it is mentioned in surveys (Wen et al. 2018). However, such recommendations for action to increase the quality of UGS for the elderly are rather general and tend to ignore the spatial context. In order to effectively meet a large share of the demand of elderly people for UGS, it is advisable to conduct a spatial prioritisation, i.e. selecting those spaces for improvement where demand is especially high.

The fact that elderly people often have declining mobility (Robert Koch-Institut 2015) makes it more difficult for them to benefit from UGS and their ecosystem services. This is one reason why special consideration of this user group in planning issues is vital to achieving greater environmental justice (Enssle and Kabisch 2020). In-depth studies have considered UGS accessibility based on various socio-demographic variables, such as socio-economic status (Wolch et al. 2014, Li and Liu 2016, Schüle et al. 2017), occupation, educational level (You 2016) or age (Wen et al. 2020). The Covid-19 pandemic has once again highlighted the problem of inequitable access to high-quality UGS and thus also to its ecosystem services (Gray and Kellas 2020). Nevertheless, only a handful of studies have considered the spatial distribution of UGS regarding quality when drawing conclusions on equitable provision (Kronenberg et al. 2020).

In the following, therefore, we present an approach that takes account of the needs of UGS users, especially elderly people, when assessing UGS quality and supply. To this end, we address the mentioned research gaps while making use of existing approaches, such as that of Grunewald et al. (2017) to estimate UGS supply. Further, we develop concepts for evaluating UGS in terms of user needs and consider the question of justice in the supply of UGS. By comparing the needs of the elderly with the actual features of UGS using a transdisciplinary approach, it is possible to determine which UGS are of 'high quality', i.e. they already meet the needs of the elderly. Conversely, we can also identify low-quality UGS that do not meet these needs. In combination with population statistics, this approach offers the possibility of a more in-depth calculation of the supply of UGS for elderly people at city and district level and, thus, also the provision of several cultural ecosystem services. The approach is demonstrated for the City of Dresden, Germany, using high-resolution data.

In so doing, we aim to answer the following research questions:

1. Which demands do elderly people place on UGS and do these differ from the general population?
2. How do these potentially different demands for UGS features affect the assessment of UGS quality?
3. How is the supply of UGS for the elderly and the general population affected by considerations of quality?
4. What implications does the user-orientated supply of UGS have for urban planning?

Methods

Study area

We chose the City of Dresden to test our approach. Covering an area of almost 330 km^2, the capital of Saxony has a population of over 550,000, making it Germany's twelfth largest city (Deutscher Städtetag 2019). Dresden is a suitable case study for our investigation as – like many of the country's eastern cities – it has a strongly ageing population: 23.9% of Dresden's inhabitants are over 65 years, the ninth highest proportion of all European cities with over 250,000 inhabitants (Statistisches Bundesamt 2016) and the highest-ranked Germany city. For this reason, there is a high demand for UGS suitable for the elderly.

The IOER Monitor of Settlement and Open Space Development (https://www.ioer-monitor.de/en/) provides remote sensing-based information on the proportion, as well as extent, of urban green in all German cities (Meinel et al. 2022). In Dresden, 26.5% of the urban area is covered with vegetation. This is mainly contributed by open spaces, such as city parks, allotment gardens or cemeteries, but also by private green and roadside vegetation. However, due to its large population, the green-covered area per inhabitant in Dresden is only 288.8 m² and well below the average value of 573 m² per inhabitant for all German cities with more than 50,000 inhabitants (Leibniz Institute of Ecological Urban and Regional Development 2022). An accessibility analysis (Grunewald et al. 2017) showed that only 60.2% of local people live within walking distance of UGS, the seventh lowest value for German cities with over 50,000 inhabitants (Leibniz Institute of Ecological Urban and Regional Development 2022). More than a third of the population is undersupplied with UGS. In view of these problems in the supply of UGS, it is important to identify where these deficits occur, whether they are exacerbated when UGS quality is taken into account and whether elderly people are more affected than the general population.

Definition of terms

Unfortunately, we lack a universally accepted definition or uniform criteria for the term “green space” (Whitten 2020). As such ambiguity also affects other terms in this field, we will here introduce and define some central concepts. As UGS, we count all those areas that are at least partially vegetated and have a minimum size of 1 hectare, a definition employed in other studies (e.g. Grazuleviciene et al. 2014, Knobel et al. 2021). Previous studies have additionally assumed a maximum travel distance, as we do here (Van Herzele and de Vries 2011, Stessens et al. 2017). Various studies have highlighted the importance of the size of UGS (e.g. Zandieh et al. 2019); in particular, elderly people are more likely to need larger UGS to pursue their activities (Macintyre et al. 2019), especially *walking*. Therefore, we decided to set 1 hectare as the minimum size of UGS in order to ensure sufficient space for *walking*. This lower boundary can be adjusted in subsequent studies if other user groups are the focus of interest. UGS can be parks, forests, brownfields, areas such as playgrounds or cemeteries with limited opening hours, semi-public areas, such as allotments as well as green areas attached to housing blocks. The definition excludes fully sealed areas, agricultural land, roadside greenery and private gardens. UGS features encompass not only furniture, such as benches or bins, but all criteria that respondents indicated as relevant to visiting an UGS. Therefore, in addition to a wide variety of (technical) facilities, features such as cleanliness or tranquillity can also characterise UGS. We define the *elderly* as all persons aged 60 and over, a definition also employed by the Federal Statistical Office of Germany (Statistisches Bundesamt (Destatis) 2020). *UGS justice* for the elderly means that they enjoy the same access to high-quality UGS as other sections of the population. This definition is inspired by Kronenberg et al. (2020), who state that, when different socio-economic groups enjoy varying levels of provision or access to UGS, this can be interpreted as injustice. By additionally considering user needs, we not only address distributive justice, but combine it with interactional justice (Enssle and Kabisch 2020). The *UGS quality* is determined by comparing the supply of UGS with the demands of users and will, thus, depend on the particular needs of each section of the population. In this way, mismatches between supply and demand can be used to identify areas for action in urban planning (Bertram and Rehdanz 2015, La Rosa et al. 2018). UGS that meet most of the specific demands of a user group are designated as high quality, whereas UGS that meet only a few demands are low quality.

Data sources

Our spatial analysis made use of datasets on UGS generated in a previous study (Krellenberg et al. 2021). These datasets identify all relevant UGS in the City of Dresden and include a range of indicators for UGS features. Various data sources, such as municipal (open) data from the City of Dresden, VGI data from OpenStreetMap (OSM) and social media posts, were processed to calculate these features. The generated datasets are freely available in German language (Leibniz Institute of Ecological Urban and Regional Development 2021). The table given in Suppl. material 1 names the data sources used to process each indicator. Using an automated approach described in Ludwig et al. (2021), UGS polygons were generated as a spatial reference unit to calculate the indicators. The polygon generation is based on modelling assumptions on physical barriers, the level of greenness, as well as public accessibility. In the model, barriers are defined as elements of the road, rail and water network, as well as boundaries created by certain combinations of adjacent land-use classes. Our Dresden case study also makes use of additional topographic data on city blocks and official geometries for “Parks and Green Spaces” and “Playgrounds”, which are freely available via the Cities Open Data Portal (opendata.dresden.de).

To map the demand for UGS, high resolution population data was acquired from the local statistical agency for 5,514 of Dresden’s 11,510 city blocks as of 31 December 2019 (Statistikstelle der Landeshauptstadt Dresden). For each city block, the total population is given, as well as the population of those aged 60 and older. It should be pointed out that population figures for under-occupied blocks may be distorted due to the fact that, if only one to three persons are registered in a block, they are either deleted or assigned to other blocks. For the dasymetric mapping process, we used a 3D-building model in Level of Detail 1 (LoD1-DE) from the official state surveying office (Staatsbetrieb Geobasisinformation und Vermessung Sachsen) (see Section "UGS buffering, dasymetric mapping and assessing UGS supply for users (work steps 5 - 7)").

Methodological framework and data collection

In order to answer the research questions, we devised the workflow shown in Fig. 1 consisting of seven major work steps:

1. survey implementation;
2. statistical analysis of the survey results;
3. UGS assessment by calculating the UGS quality;
4. classification of high-quality UGS;
5. buffering of (high-quality) UGS;

6. population calculation for each building by dasymetric mapping; and
7. assessment of UGS supply for users.

The individual work steps are explained in detail below.

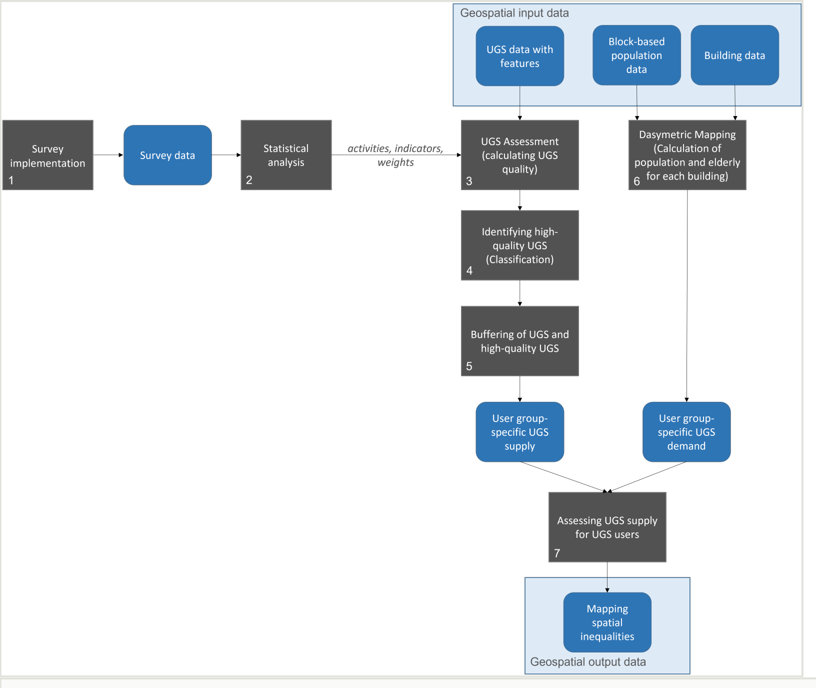

Figure 1.

Methodological workflow (blue: input/output data; grey: processing steps).

Survey implementation (work step 1)

To ascertain the opinions and needs of UGS users, we conducted two surveys (see Suppl. material 2 and Suppl. material 3). The first was carried out in the spring of 2019 as an online survey of several thousand people across Germany, selected via our own mailing lists and those of our project partners. In this questionnaire (Suppl. material 2), we asked for information on those activities which UGS users carry out most frequently, as well as which UGS features they believe should be available. The respondents could choose up to six activities: three from a list of 11 ‘active’ (*badminton, cycling, dog walking, fitness, frisbee, jogging, skating, soccer, swimming, volleyball or walking*) and three from a list of seven ‘passive’ activities (*eating and drinking, meeting friends, observing nature, playground, reading, relaxing and sunbathing*). The activity lists were compiled on the basis of a previous intensive literature research. In addition, the participants had the opportunity to identify one activity that was not included on the lists. In this way, our analysis was not restricted to the activity *walking*, as was the case in several previous studies (e.g. Zhai and Baran 2017). For each selected activity, the respondents could then specify an unlimited number of relevant UGS features in open text fields; thereby, the survey only captured those features which the respondents themselves believed to be significant. The survey also took account of various socio-demographic factors, such as age and gender.

For the second survey (Suppl. material 3), the collected open responses on UGS features per activity were manually clustered, based on authors' expert knowledge. For this purpose, the same or similar terms were assigned to a group. For example, the feature *cleanliness* includes statements such as *cleanliness*, *no dirt*, *no broken glass* and *no dog excrement*. We included only those features mentioned by at least 5% of UGS users and for which we were able to develop indicators. By limiting the features to those most frequently mentioned in the open text field in survey 1, each feature should have a particular relevance for the group of elderly users. While the second survey was distributed online via the same channels as the first, an analogue version was also provided at public scientific-related events, namely the "Long Night of Science" and "Science Tram", both held in Dresden. The analogue version of survey 2 only named the six most frequently mentioned activities from survey 1. The respondents were again asked to choose their preferred activities in UGS. For each activity, the most frequently mentioned UGS features from the first survey were listed. The respondents were asked to indicate how important they regarded these features on a Likert scale from 0 (very unimportant) to 10 (very important). The final importance score of the UGS features of each activity was calculated by averaging the respondents' scores. In equation (2) below, this is indicated as $I_{O_{FA}}$, named as the *original mean importance score*. The second survey also took account of socio-demographic factors.

Before conducting the socio-demographic evaluation, we excluded those cases where no age was indicated or where the age information was obviously incorrect. Table 1 lists the remaining cases, classified by gender and separately for the elderly. Of an initial 497 respondents to the first survey, 29 were excluded, leaving a sample of 468. Around a quarter of respondents were male and three-quarters female. A total of 83 respondents were at least 60 years old, i.e. approx. 18%, a much lower figure than the German population as a whole (28.2%) (Statistisches Bundesamt (Destatis) 2020). While this does not affect the evaluation of the needs of the elderly with regard to UGS, it could have a small effect on the results for the overall sample. The gender distribution is somewhat skewed in the sample group of elderly respondents in that almost 80% are women. Some 472 people participated in the second survey, of which 83 were excluded. About one third of respondents were male and two-thirds female. Sixty-one people were at least 60 years old, i.e. approx. 16%. Here the gender distribution amongst the elderly is similar to that of the overall sample.

Socio-demographic analysis and calculation of feature weights (work step 2)

The Eta coefficient was used to examine the correlation between the age of the respondents (metric) and the choice of activity (nominal). To interpret the direction of correlation, we considered the distribution of the number of mentions. The effect size was calculated using Pearson's r. According to Cohen (1988), the effect size can be small (≥ 0.10), medium (≥ 0.30) or large (≥ 0.50). To determine the significance of the correlation, an ANOVA test was performed with the level of significance set at $p < 0.05$. All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, N.Y., USA).

Table 1.

Overview of participants in the two surveys showing the overall sample and the elderly sample.

Gender	**Survey 1**		**Survey 2**	
	Overall sample	**Elderly sample**	**Overall sample**	**Elderly sample**
Female	339	64	250	38
Male	121	18	129	23
Other/no data	8	1	10	0
Total	468	83	389	61

The results of the two surveys form the basis of the UGS feature weights. In order to calculate the specific UGS feature weights that appeal to the elderly, we initially only evaluated the answers of respondents aged 60 and over. From data gathered in the first survey, we could determine how often an activity was mentioned, as well as the total number of mentions. These figures are given in Table 2. The data from the second survey enabled us to determine the importance scores of the corresponding UGS features for the three most frequently mentioned activities. These importance scores are shown in Table 3. We focused on the three most important activities not only to take account of other activities than *walking* (Wen et al. 2018), but also to have the highest possible number of cases to ensure more reliable values. Since the importance scores for the individual features were relevant rather than their connection to a specific activity, the importance scores of each feature were simply combined. To this end, a weighting factor W_{FA} was first determined for each feature F in an activity A, whereby the importance score is set in relation to the number of mentions. The weighting factor is calculated as follows:

Table 2.

The ten most frequently selected activities (absolute and relative) in the overall sample and the elderly sample.

Overall sample [N = 468]			**Elderly sample [N = 83]**		
Activity	**Count**	**Percentage** [%]	**Activity**	**Count**	**Percentage** [%]
Walking	372	79.5	Walking	67	80.7
Relaxing	330	70.5	Relaxing	61	73.5
Observing nature	283	60.5	Observing nature	60	72.3
Cycling	254	54.3	Cycling	42	50.6
Meeting friends	178	38.0	Reading	24	28.9

Overall sample [N = 468]			Elderly sample [N = 83]		
Activity	**Count**	**Percentage** [%]	**Activity**	**Count**	**Percentage** [%]
Reading	135	28.9	Playground	17	20.5
Jogging	123	26.3	Meeting friends	16	19.3
Eating and drinking	119	25.4	Sunbathing	16	19.3
Playground	93	19.9	Badminton	14	16.9
Sunbathing	92	19.7	Dog walking	13	15.7

Table 3.

Importance scores for UGS features differentiated by the three activities ‘walking’, ‘relaxing’ and ‘observing nature’ for the overall sample and the sample of elderly respondents.

	Original importance scores for…					
	walking		**relaxing**		**observing nature**	
UGS feature (*F*)	**Overall sample**	**Elderly sample**	**Overall sample**	**Elderly sample**	**Overall sample**	**Elderly sample**
Naturalness	8.42	8.88	7.81	7.97	9.01	9.16
Tranquillity	8.15	8.50	8.30	8.42	8.76	8.94
Structural diversity	7.81	8.65	-	-	8.65	8.78
Animals	-	-	-	-	7.99	8.09
Much greenery	8.77	9.46	8.66	8.74	9.12	9.16
Trees	8.65	9.04	8.87	8.89	9.09	9.38
Benches	5.83	7.23	6.84	7.47	5.90	7.66
Water elements	6.69	7.19	6.61	6.92	7.13	7.34
Aesthetics	6.91	6.77	6.58	6.34	5.80	5.94
Cleanliness	8.17	8.50	8.49	8.29	8.46	8.22
Meadow	7.02	7.85	8.03	7.76	-	-
Shade	-	-	8.13	8.03	-	-

$$W_{FA} = \frac{N_{A_i}}{\sum_{i=1}^{n} N_{A_i}} \quad (1)$$

where N_{A_i} describes the number of mentions for *i*-th activity and *i* depends on *n*, the number of occurrences of a feature in activities. When *n* is at its maximum value of 3, the UGS feature *F* occurs in all three activities. For example, when *naturalness* is considered an example feature and *walking* an example activity, it can be clearly seen in Table 3 that *naturalness* occurs not only in *walking*, but in all three activities. Therefore, the weighting factor W_{FA} of this feature for the activity *walking* was calculated by dividing the number of mentions of *walking* by the total number of mentions of all three activities. The results of this calculation are given in Suppl. material 4.

The weighting factor, therefore, depends not only on how often an activity was mentioned in the first survey, but also for how many of the three activities an UGS feature is regarded as important. This weighting factor was then multiplied by the original mean importance scores $I_{O_{FA}}$ assigned by the surveyed elderly for an UGS feature of a specific activity:

$$I_{W_{FA}} = I_{O_{FA}} \times \mathrm{W}_{FA} \quad (2)$$

Using the weighted importance scores of each feature of an activity $I_{W_{FA}}$ (Suppl. material 5), the same UGS features of different activities were combined to one importance score for every UGS feature I_F by summing as follows:

$$I_F = \sum_{i=1}^{n} I_{W_{FA_i}} \quad (3)$$

where *n* is the same as in equation (1). To obtain the final UGS feature weights, the importance scores I_F assigned by the surveyed elderly to an UGS feature were combined as follows:

$$W_{F_k} = \frac{I_{F_k}}{\sum_{k=1}^{n} I_{F_k}} \quad (4)$$

where *n* is the number of total UGS features. The results of equations 3 and 4 are given in Table 4. All calculations were performed twice: once with the answers of the elderly and once with the answers of the overall sample. This provided a basis for comparison and to determine which UGS features are specifically relevant for the elderly.

Table 4.

Combined importance scores and weights for the UGS features of the overall sample and the elderly sample, as well as their differences.

	Overall sample		**Elderly sample**		**Difference**	
UGS feature (*F*)	**Importance score**	**Feature weight**	**Importance score**	**Feature weight**	**Importance score**	**Feature weight**
Naturalness	8.39	0.089	8.67	0.089	0.28	0
Tranquillity	8.38	0.089	8.61	0.088	0.23	-0.001
Structural diversity	8.17	0.087	8.71	0.089	0.54	0.002
Animals	7.99	0.085	8.09	0.083	0.10	-0.002
Much greenery	8.83	0.094	9.13	0.094	0.30	0
Trees	8.85	0.094	9.10	0.093	0.25	-0.001
Benches	6.19	0.066	7.45	0.076	1.26	0.01
Water elements	6.79	0.072	7.15	0.073	0.36	0.001
Aesthetics	6.48	0.069	6.37	0.065	-0.11	-0.004
Cleanliness	8.36	0.089	8.34	0.086	-0.02	-0.003

	Overall sample		Elderly sample		Difference	
UGS feature (*F*)	**Importance score**	**Feature weight**	**Importance score**	**Feature weight**	**Importance score**	**Feature weight**
Meadow	7.49	0.080	7.81	0.080	0.32	0
Shade	8.13	0.086	8.03	0.082	-0.10	-0.004

Calculation and classification of the UGS quality (work steps 3 + 4)

All the relevant UGS features were counted for all the types of UGS. For this purpose, a suitable indicator had to be developed for each UGS feature. Our indicators were selected after an intensive review of the relevant literature, as well as our own considerations. A more detailed explanation of the creation of the indicator set can be found in Krellenberg et al. (2021). Suppl. material 1 gives an overview of the relevant UGS features and the indicators used for their evaluation. The data for the indicators was drawn from diverse data sources, named in Suppl. material 1 and explained in Section "Data sources". After indicator values had been determined for each UGS feature, these values were normalised in the range 0 (minimum) to 1 (maximum) to facilitate comparison.

In order to determine the UGS quality Q_{GS}, the normalised UGS feature indicator value V_{N_k} was multiplied by the respective UGS feature weight W_{F_k}. The individual weighted values of the UGS features were then summed:

$$Q_{GS} = \sum_{k=1}^{n} W_{F_k} \times V_{N_k} \quad (5)$$

where *n* is the number of UGS features. An example of the process of calculating the V_{N_k} and the Q_{GS} is given in Suppl. material 6.

We divided the UGS qualities into three classes (high, medium and low quality) using *Jenks Natural Breaks* classification method. This ensured that the values were as homogeneous as possible within each class and as heterogeneous as possible between classes. In so doing, the classes are derived from the data and not from arbitrarily defined limits (Slocum et al. 2008). We calculated the class boundaries for the overall sample and also applied these to the group of elderly respondents.

UGS buffering, dasymetric mapping and assessing UGS supply for users (work steps 5 - 7)

Basically, a person's supply of UGS is assessed in terms of accessibility. Here, we assume that the supply is sufficient if a person has access to at least one UGS. We adopted the approach of Grunewald et al. (2017) to spatially determine the catchment areas of all UGS larger than one hectare, based on a defined maximum straight-line (Euclidean) distance. Since we were particularly interested in the supply of UGS to the elderly, we decided to set a maximum Euclidean distance of 300 m as this value is approximately equivalent to a walking distance of 500 m (Richter et al. 2016). The 300 m Euclidean distance is also recommended by the European Commission for assessing access to public open areas, which also encompasses UGS (European Commission 2001). We did not increase this distance value for larger UGS, as some other studies have done (e.g. Grunewald et al. 2017, Feng et al. 2019), because we assume that, for our elderly target group, 500 m is already a considerable distance.

We used a standard spatial buffering approach to analyse accessibility (e.g. Grunewald et al. 2017, Dennis et al. 2020). By buffering all UGS polygons to a distance of 300 m, we can identify the areas in the city with no UGS supply. Further, by selecting UGS according to the quality class ‘high’, we can identify those areas with no access to high-quality UGS. By intersecting these with the population data, it is possible to calculate the proportion of the total population, as well as of the elderly who are provided with high-quality UGS. We refined the official city block statistics on population by means of dasymetric mapping (Eicher and Brewer 2001). Specifically, we applied a volumetric approach (Lwin and Murayama 2009), whereby the volume of buildings was used to estimate the population per building by disaggregating the absolute population (in total and for the age group 60 years and older) from the official city block statistical data (see Section "Data sources"). The model was based on 3D building models in LoD1, where building usage is also indicated. Only buildings with residential use were considered in the estimation; all non-residential buildings were assigned a population of 0. In this way, we could estimate for each building (represented by its centroid) the total number of residents, as well as those aged 60 and over. Compared to the standard statistical data at city block level, this refinement has the advantage of giving a more realistic picture by taking account of the building structure. Inspired by Kronenberg et al. (2020), justice in the supply of UGS was determined by comparing the percentage provision to the elderly with that of the general population.

Results

UGS use by the elderly

The first survey was designed to collect data on those activities carried out by respondents in UGS. Table 2 lists the ten most frequently selected activities, the number of selections and the frequency of mention in the overall sample, as well as in the group of elderly respondents.

The order of the first four most frequently mentioned activities is the same in the overall sample and the group of elderly respondents. Some other activities such as *eating and drinking* or *dog walking* appear just in one of the two groups. Regarding the distribution, only a few correlations could be identified between the age of the respondents and preferred activities. Specifically, a slight positive correlation was found between the increasing age of respondents and the preferential use of UGS for *relaxing* (η = 0.15, p = 0.001) and *observing nature* (η = 0.21, p < 0.001). In contrast, a slight negative correlation was identified between the increasing age of respondents and the popularity of the following four activities: *jogging* (η = 0.26, p < 0.001), *volleyball* (η = 0.14, p = 0.002), *eating and drinking* (η = 0.25, p < 0.001) and *meeting friends* (η = 0.30, p < 0.001). For all further analyses in our study, we considered only the three most frequently mentioned activities, namely *walking*, *relaxing* and *observing nature*.

Unfortunately, the results of the two surveys are not directly comparable due to their different formats and practical implementation (digital, analogue).

Activity-related UGS features

In order to identify those criteria best suited to estimating the quality of UGS, we asked the survey respondents to indicate which features would be required to carry out their chosen activity. Of the 372 people who indicated *walking* as a relevant activity, 353 also mentioned UGS features, giving a total sample of 530 UGS features. We then clustered this sample into 20 feature groups (see Suppl. material 7). Of the 330 people who indicated *relaxing* as a relevant activity, 322 specified a total of 587 UGS features, which were then clustered into 21 groups (see Suppl. material 8). Of the 283 people who indicated *observing nature* as a relevant activity, 257 specified a total of 471 UGS features, subsequently clustered into 18 groups (see Suppl. material 9). In evaluating the data of survey 2, we considered only those UGS feature groups mentioned by at least 5% of the users of a certain activity and represented by an indicator. This resulted in the identification of 10 relevant UGS features for each of the three activities (Table 3). The original importance score of the overall sample for *walking* is derived from 218 answers, *relaxing* from 274 and *observing nature* from 143. Of the elderly group of respondents, 26 assigned an importance score for *walking*, 38 for *relaxing* and 32 for *observing nature*. Table 3 shows why it is important for an accurate analysis to consider activities other than just *walking*: Firstly, the green space features *animals* and *shade* would be missing from the calculation of the UGS quality. Secondly, the weights of the UGS features are seen to differ significantly between the various activities. For example, the UGS feature *aesthetics* is more important in *walking* than in *observing nature*. In turn, the *water elements* and *structural diversity* are more important in *observing nature* than in *walking*.

The original importance scores of the three activities were combined as described in Section "Socio-demographic analysis and calculation of feature weights (work step 2)" and shown in Suppl. material 4 and Suppl. material 5, giving the importance scores of each UGS feature I_F listed in Table 4. The top three UGS features for both the overall sample and the elderly respondents are *much greenery*, *trees* and *naturalness* (although in a slightly different order). These features basically relate to the extent and form of vegetation in UGS. On average, the importance scores differ by 0.28 (σ = 0.35). The greatest difference was found for the UGS feature *benches* (1.26) and the smallest for *cleanliness* (-0.02). Nine of the UGS features show a positive difference, meaning that the importance score of the elderly respondents is higher than the overall sample. Due to our calculation steps and multiple aggregated values, no variances can be quantified. For this reason, it cannot be ruled out that the observed differences are of a random nature. To determine the quality of the UGS, it is necessary to give a weighting to the various UGS features. Here, the values are listed under W_{F_k} in Table 4.

These feature weights indicate how important the UGS features are both for the overall sample and for the group of elderly respondents. The greatest difference between the two groups is seen in the UGS feature *benches* (0.01). For three of the UGS features, i.e. *naturalness*, *much greenery* and *meadow*, the W_{F_k} values are identical to the third decimal place.

UGS quality and spatial distribution

As described in Section "Calculation and classification of the UGS quality (work steps 3 + 4)", the quality of UGS is the sum of all weighted UGS features related to the three most frequently mentioned activities, namely *walking*, *relaxing* and *observing nature*. Due to the slight differences in UGS feature weights between the overall sample and the elderly, these differences have little impact on the UGS quality ratings (see Table 5). In the overall sample, the lowest quality score for UGS is 0.151 and the highest 0.622. For the elderly, we obtain a minimum quality of 0.155 and a maximum quality of 0.626. Using the classification method *Jenks Natural Breaks*, all 997 UGS larger than one hectare were divided into the quality classes *low*, *medium* and *high*. The histogram in Fig. 2 shows the distribution of the UGS quality scores for the elderly along with the class boundaries. Table 5 gives the specific value ranges of the three classes and the number of UGS in each class for both the overall sample and the elderly. Applying these findings to the quality of Dresden's green areas, we can say (using the results of the overall sample) that approximately 30% of UGS are of low quality in terms of satisfying the needs of the general population. Further, more than 40% are of medium quality and 30% high quality. For the elderly, the values are almost identical. Only 19 additional UGS are assigned to the medium-quality class and five to the high-quality class.

Table 5.

Value range of the quality classes and number of UGS sites per quality class for the overall sample and the elderly sample.

Quality class	**Value range**	**Number of classified UGS sites based on**:	
		Overall sample	**Elderly sample**
low	0.151 – 0.331	292	268
medium	0.332 – 0.446	409	428
high	0.447 – 0.626	296	301

Fig. 3 maps the quality classes for Dresden's UGS (spaces > 1 ha), based on the ratings of the elderly respondents. It can be clearly seen that (ignoring the large area of contiguous forest to the north-east), inner-city areas are less green than the outskirts. Moreover, large UGS, for example, in the north and east, are of at least medium quality. Spatially, there are no areas with exclusively high- or low-quality UGS; instead, the distribution appears to be balanced. Of course, the question of whether this balanced distribution also ensures an equitable supply depends on the resident population in the various catchment areas of UGS sites. This will be investigated in the next section.

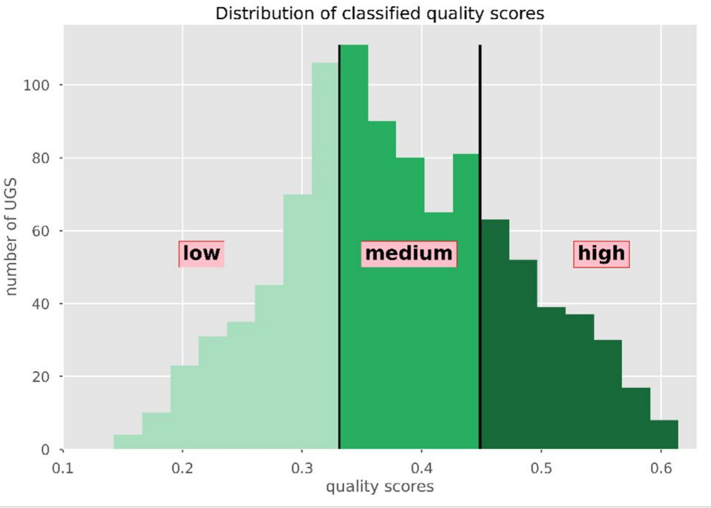

Figure 2.

Histogram of the number of UGS sites per quality score with natural breaks classifying the quality into low, medium and high.

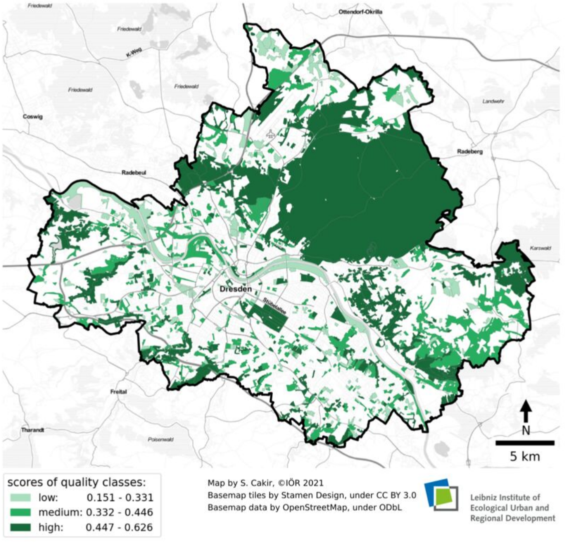

Figure 3.

All of Dresden's UGS classified as either low, medium or high quality.

Supply of UGS to the elderly

To determine the supply of UGS to local residents, in particular the elderly, we calculated the catchment areas of UGS. By intersecting the catchment areas with the building-based population data of Dresden, we found that 93.9% of all buildings are supplied with UGS and 55.7% with high-quality UGS. Fig. 4A shows which areas within the city boundary are supplied with at least one UGS (highlighted in green).

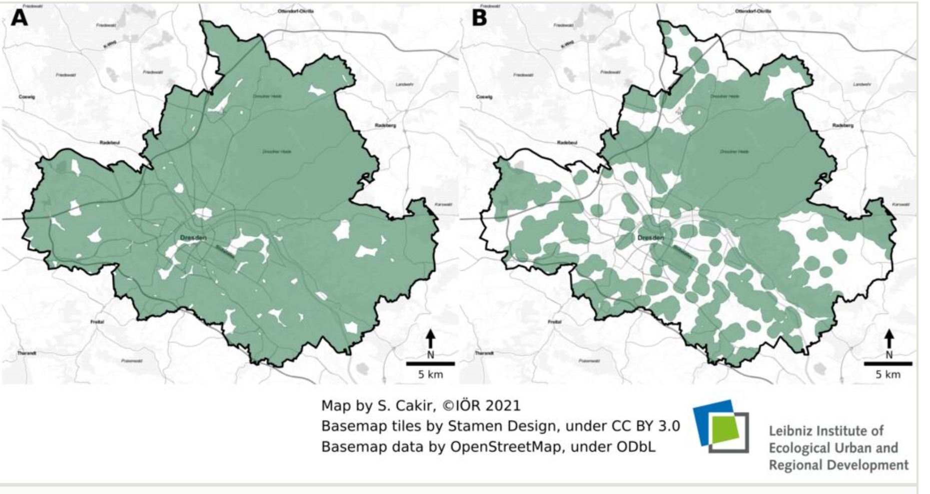

Figure 4.

Areas in Dresden supplied with UGS (A) and high-quality UGS (B) (highlighted in green), derived by buffering the high-quality areas to a radius of 300 m.

By intersecting the catchment areas with the population data, we found that 499,036 people, i.e. 89.7% of the population, have access to at least one of the UGS. Considering only high-quality UGS, the supply rate is 47.6%. In comparison, of the nearly 130,000 elderly people in the City of Dresden, 119,000 or 91.7% have access to at least one green space; further, 72% have access to more than one of the UGS. Yet, if the quality of UGS is taken into account, only 51.7% of elderly citizens are provided with at least one high-quality UGS site. Fig. 4B shows those areas within the city boundaries where the elderly have access to at least one high-quality UGS (highlighted in green).

Across Dresden, there are local disparities in the number of elderly citizens without access to UGS. Fig. 5 shows the absolute numbers of elderly people living in potentially non-supplied areas at city block level. The white areas are either unpopulated (with no demand) or located within the 300-m buffer of a high-quality UGS and, thus, well supplied. Dark red areas indicate high densities of elderly per ha with no access to high-quality UGS (green coloured areas). It can be seen that elderly people living in the north, east and far west of Dresden are generally well supplied with high-quality UGS. In contrast, the inner city and parts of the south-east, where many elderly citizens live, have a poor supply.

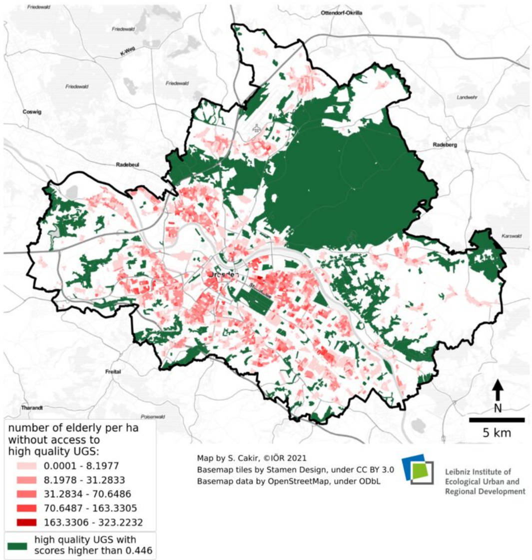

Figure 5.

Access to high-quality UGS identified at building level, but mapped on block level. White blocks within the city boundary are well-supplied, dark red areas poorly supplied. High-quality UGS are highlighted in green.

Discussion

Demands of the elderly on UGS

Our first research question considered the demands placed by elderly people on UGS and whether these differ from the general population. The significant correlations revealed by our analysis are largely consistent with those of previous studies, namely that demand decreases with age for sporting activities, such as *jogging* (Ode Sang et al. 2016, Gozalo et al. 2019, Ode Sang et al. 2020) as well as socialising activities, such as *meeting friends*; this is accompanied by an increase in demand for nature-related activities, such as *observing nature* (Schipperijn et al. 2010). In contrast, earlier studies found no correlation between age and demand for the activity *relaxing* in UGS (Conedera et al. 2015) and a negative correlation between age and the demand for *stress reduction* (Schipperijn et al. 2010), which in our study would be classified as an instance of *relaxing*. This shows not only how ambiguously the activity *relaxing* is defined, but also how the definition of terms can influence the findings.

Our results show that the level of demand for six out of the considered 18 activities is dependent on age. Thus, when selecting those features by which to assess the quality of

UGS for the elderly, it is clearly essential to focus on activities that become more relevant with age. This confirms our decision to include the activities *walking*, *relaxing* and *observing nature*. Even though *walking* is not just relevant for elderly people, it is the most frequently mentioned activity in our survey as well as in previous surveys (e.g. Duan et al. 2018, Fischer et al. 2018, Palliwoda et al. 2020, Shuvo et al. 2020) and has already been considered by several other studies (Wen et al. 2018). Fischer et al. (2018) confirmed that the activities *relaxing* and *observing nature* are important for citizens throughout Europe. In addition, all three activities can be carried out on all types of UGS, in contrast to activities, such as *cycling* or other sports, which may be prohibited on some UGS, such as cemeteries or allotments.

Some of the UGS features that the surveyed elderly people named as important were also identified by previous studies as relevant for the elderly (or leading to increased activity), such as *tranquillity* (Aspinall et al. 2010, Arnberger et al. 2017), *shade* (Arnberger et al. 2017), *trees* (Aspinall et al. 2010), *aesthetics, benches* (Aspinall et al. 2010, Chang 2020) and *water elements* (Arnberger et al. 2017). In contrast to our study, the aforementioned studies did not offer any comparison to the general population, making it impossible to say whether the UGS features are specifically relevant for elderly people.

In fact, we find some differences when comparing the importance scores of features indicated by the elderly with those of the general population, for example, *benches*, *structural diversity* and *water elements*. Specifically, elderly respondents gave higher importance scores on average than the general population, especially for the UGS feature *benches*. These particular demands are reflected by greater levels of dissatisfaction amongst the elderly for existing UGS features (Gozalo et al. 2018). The differences in importance scores between the general population and the elderly people confirm the findings of other studies that age, amongst other factors, affects the demands placed on UGS. Furthermore, these disparities underline the usefulness of the approach of examining different user groups individually in order to increase the use of UGS (Schipperijn et al. 2010). In fact, it has been shown that, when the needs of elderly people are met, there is an increased frequency of visits to UGS (Gibson 2018). This means that UGS perceived as better equipped with features are more likely to be visited than when poorly equipped.

Impact of the demands of elderly people on UGS quality assessment

In a second step, we used our approach to investigate how the disparate demands of the elderly and the general population affect the assessment of UGS quality. In Dresden, just under a third of all UGS are of high quality in relation to the demands of elderly citizens. The authors are not aware of any other study that has determined a quality score for all UGS in a city via a survey of user demands and examined the proportion of high-quality UGS. In similar studies, UGS quality was determined without any consideration of user demands (Stessens et al. 2017, Shuvo et al. 2020) and applied only to individual UGS sites in a city (Shuvo et al. 2020) or quality was not related to specific UGS sites (Akpinar 2016, Fongar et al. 2019). Yet, it is only by considering all UGS in a city that it is possible to identify areas for action in spatial planning; unfortunately, such assessments are still generally lacking (Brzoska and Spage 2020). In the case at hand, Dresden's UGS seem to meet the needs of elderly citizens slightly better than those of the general population. However, the minor differences in the importance scores lead to small differences between the elderly and the general population in the quality scores and the number of UGS in the individual quality classes (see Table 5). This is also due to our calculation method, an issue we address in Section "Methodological issues and further research".

Influence of the demands of elderly people on the supply of UGS

Our research on the impact of elderly people's demand for UGS in Dresden found that supply is generally high and that there is little difference between the level of supply to the elderly and to the general population. Compared to other studies (e.g. Gong et al. 2016, Wüstemann et al. 2017, Sikorska et al. 2020), we determined a high general supply of UGS to about 90% of the population. This value is significantly higher than that given by the Leibniz Institute of Ecological Urban and Regional Development (2022). In particular, we can say that the proportion of elderly provided with UGS is 2% higher than the general population. In the case of high-quality UGS, the difference is 4.1%. It can be deduced from this that the group of elderly people in our test city of Dresden enjoys a similar level of supply of UGS as the general population; consequently, we can state that there is a just distribution of UGS in relation to the investigated socio-demographic group. This finding is due to the small difference in importance scores between the two examined groups and, thus, the small difference in the number of high-quality UGS. Other studies have found divergent results in this regard: in Warsaw, for example, elderly residents were found to have a lower supply of UGS than the general population (Sikorska et al. 2020).

These considerations serve to highlight the effects of methodological differences in approach, for example, when alternative acceptable walking distances to UGS or definitions of what counts as UGS are adopted and the importance of taking these disparities into account (Zepp et al. 2020). Rigolon (2016) pointed out that the calculation method, the adopted definitions, as well as socio-demographic aspects, will strongly influence the results. In our study, for instance, we use a more expansive definition of UGS than most of the studies mentioned above by also considering semi-public UGS. Such semi-public UGS, many of which are informal in nature, offer significant potential to increase the total provision of UGS (Sikorska et al. 2020). The total supply of UGS is significantly underestimated when such informal areas are ignored (e.g. Rupprecht and Byrne 2014, Sikorska et al. 2020). However, unless municipality owned, access to these informal spaces is not guaranteed over the long term or may be subject to other restrictions (Rupprecht and Byrne 2014). In addition to methodological differences, cultural factors in other countries cannot be excluded as a cause of different levels of supply.

Implications for urban planning

Information on the provision of UGS can help urban planners ensure that cities remain livable (Mathey et al. 2021). Although our results show that elderly people in Dresden are not generally disadvantaged in the supply of UGS, special attention should be paid to spatial planning in those areas identified as deficient in suitable UGS. Such areas where demand is not being met due to a lack of UGS features also emerged in other studies as points of action for urban planning (La Rosa et al. 2018). Due to the great importance of UGS for the health of the elderly (e.g. Kondo et al. 2018) and the fact that lack of access to high-quality UGS is the main reason why elderly people are not sufficiently active in local UGS (Shuvo et al. 2020), it is vital to ensure that this section of the population be secured of a good supply of nearby UGS. Due to the positive correlation between frequency of visits and quality, it is vital that such UGS be of high quality (Fongar et al. 2019). Informal green spaces can also be used for this purpose (Sikorska et al. 2020). However, if urban planners are considering informal green spaces and are willing to preserve them in a permanent way to provide for the population, in most cases, they should not simply be left in their current state, but must first be appropriately equipped. Since it has been shown that the elderly rate certain UGS features as more important than the general population, existing UGS or informal green spaces should be specifically upgraded to high-quality UGS, for example, by providing (additional) benches. Using our approach, it is possible to identify medium-quality UGS in areas poorly supplied with high-quality UGS (see Fig. 5). In order to achieve the greatest possible impact with the least possible effort, those UGS sites should be chosen for upgrading whose catchment areas have a high proportion of elderly people. Our approach also identifies which features are currently poorly provided by UGS. These should be improved by urban planning to increase the quality of the UGS and to ensure a fair and balanced supply of UGS to all citizens. In order to improve the quality of UGS in non-supplied areas with limited financial resources, maintenance could be reduced in areas that are supplied with several high-quality green spaces and where few elderly people live. The needs of different user groups can also provoke conflicts in public spaces, for example, when elderly want a quiet green space for relaxation, but younger people would like to play football or volleyball. Here, it is the task of urban planning to find a compromise solution and enable multifunctional use of the UGS. The approach provides guidance by considering the spatial distribution of the user groups, in this case, the elderly. For a comprehensive planning basis, this analysis should be carried out for all relevant user groups and combined. In this way, it is possible to focus on the UGS features that are actually demanded by the user groups living on site.

Methodological issues and further research

Our approach represents an extension of existing concepts to analyse the provision of UGS and its cultural ecosystem services to urban residents (e.g. Schüle et al. 2017, Chen et al. 2020, Wu and Kim 2021). In addition, we have presented an approach to map and assess cultural ecosystem services by considering the quality of UGS from the user perspective rather more generally in terms of the total extent of UGS (Brzoska and Spage 2020). A significant advantage of this approach to determining the quality of UGS is that it can be applied equally to all UGS in the city, while still taking account of site specifics, i.e. UGS features. In cases where only limited municipal data are available, alternative globally-available datasets, such as Social Media or OSM data can be used. However, the quality of OSM data and representation of green-related tags may vary regionally (Ludwig and Zipf 2019, Ludwig et al. 2020), while classes, instances and their attributes can change over time (Ballatore and Zipf 2015).

However, our approach also has limitations, which we would like to address briefly. Our study only considers UGS of one hectare or larger. Other studies have shown that smaller UGS can be used for recreation; indeed, pocket parks play a particularly important role in this respect. Certainly, there is no doubt that the type of user activity will depend on the size. For example, the activity of socialising is mainly carried out on small UGS sites (Peschardt et al. 2012, Peschardt et al. 2014). Although our study confirms that socialising on UGS decreases with age and elderly people are more likely to need larger spaces for their activities (Macintyre et al. 2019), it is possible that green areas, smaller than one hectare, may be relevant to the elderly.

Our UGS basis is very broad. In particular, we also consider allotments or cemeteries, which are partly restricted in access and use. While this approach is intended to identify the maximum possible supply, in real terms, it may overestimate the provision in some areas. However, the definition of UGS can be flexibly adapted to the individual circumstances of each city: urban planners can ignore some types of UGS that they view as irrelevant (also in relation to the user group under investigation). In some areas, UGS with restricted access or use can still play an important role in ensuring a minimum, yet secure supply of UGS. In this way, urban planning can develop concepts for opening such UGS to more people.

Even if the selection of activities and UGS features for the assessment of quality is based on user surveys, it cannot be guaranteed that all relevant features are actually taken into account and that the results are free of sampling bias. Clearly, there is a predominance of women respondents in our surveys. This may have an impact on the identification of important activities and UGS features, as these are partly related to gender (e.g. Sanesi and Chiarello 2006, Ode Sang et al. 2016, Gozalo et al. 2018, Chang 2020, Stessens et al. 2020), even at an elderly age (Zhai et al. 2021). The gender bias, which occurs in both the total sample and subset of elderly respondents, affects the weighting (if at all) to the same extent. Since the survey data were collected nationally, the method can also be applied to other cities in Germany without fear of further bias. In other countries, it would be advisable to conduct the user survey first to take account of cultural differences, such as potentially alternative choices regarding preferred activities (Duan et al. 2018). Most respondents live in larger cities, but individuals from rural areas may have participated. They might have different needs for UGS or UGS might have a different importance, as could be the case for people with their own garden. To find out whether the size of the city or the location of the green space within the city matters, more in-depth analyses are necessary.

The indicators used to calculate the UGS quality are taken from Krellenberg et al. (2021). Depending on the availability of data, these can be expanded and supplemented as more comprehensive data are gathered. In our case, it was not possible to implement all features using different indicators: three features (*trees*, *shade* and *naturalness*) were at least partially calculated by the same indicator (share of tree crown area in a green space) and, thus, tree crown area has a particular impact on the quality of an UGS. However, the feature *shade*, for example, could be expanded in other studies to include building shade. Similarly, exploratory indicators that use social media data could be supported by results from surveys on aesthetics or wildlife stocks.

With regard to comparing different user groups and their evaluation of UGS features, our calculation approach is subject to certain drawbacks. Since the individual features are placed in relation to each other to calculate the final UGS feature weights, the absolute level of the importance score is no longer relevant. While many of the features differ substantially in the importance scores assigned to them by the general population and the elderly, only the feature *benches* shows a disparate value for the UGS feature weights. When comparing different user groups, our calculation approach must be revised to reveal these differences. This will enable the approach to be used in the study of other user groups, preferably by combining several socio-demographic characteristics (e.g. You 2016). For example, it can be investigated whether elderly people in poorer neighbourhoods are particularly under-supplied with high-quality UGS despite their urgent need for such UGS (Dennis et al. 2020). For this purpose, the evaluations could be divided into district or neighbourhood level and the Gini index used to determine where in the city people of one user group are suffering from a poor supply of UGS (see Kabisch and Haase 2014, Feng et al. 2019, Wen et al. 2020). This can provide cities with data to argue why they are primarily dedicated to improving the UGS access of one or the other user group, as well as to identify those UGS that require upgrading with specific features in order to achieve a balanced UGS supply. The results of our assessment approach can be communicated via web applications to urban planners, as well as to the general public (Hecht et al. 2021). In addition, the assessment approach can be embedded in interactive accessibility tools for different traffic modes and that allow the building of scenarios (Pajares et al. 2021).

In our view, there are potentials to further develop our method by directly collecting the UGS features without assigning them to specific activities. In addition, the quality of the UGS features could be included in the general calculation of UGS quality due to their positive influence on the frequency of visits (Chang 2020). In our approach, the absolute number of UGS to which access is available is irrelevant when assessing the supply of UGS; supply is given if there is access to at least one (high-quality) UGS. In future analysis, the number and quality of accessible UGS could be considered, particularly if the aim is to more accurately investigate the issue of justice. Furthermore, we adopted a fairly simple approach to analyse accessibility, namely using Euclidean distance to buffer the UGS and intersecting these with the population data. The results could be refined in future studies by taking account of the actual path length by means of network analysis (e.g. Sikorska et al. 2020) and adapting the catchment areas to the specific travel times of user groups or by considering different modes of transportation (Stessens et al. 2017). Furthermore, the population mapping approach could be refined by integrating OSM tags to better reflect partial non-residential use (Kunze and Hecht 2015).

Conclusions

We have developed an approach to analysing UGS, one that evaluates user group demands and assesses the provision of UGS to urban residents. Our findings show that elderly people are more interested in the activities of *relaxing* and *observing nature*, while demanding a higher number of *benches* in UGS than the general population. Nevertheless, these differences only have a minor impact on the quality of the UGS. The intersection of the catchment areas of the UGS with the local population showed an equitable supply of UGS to Dresden’s elderly citizens. At the same time, we determined that almost half of all elderly people are not provided with high-quality UGS.

Due to the various beneficial effects of visiting UGS, especially for elderly people, urban planners should ensure that older residents living in areas deficient in UGS be provided with access to high-quality UGS corresponding to their needs. Such improved provision of UGS would increase the positive impacts of UGS and their ecosystem services for the local population. For this purpose, the approach offers the possibility to identify which UGS should be upgraded and which features are required. Our approach can be easily transferred to other user groups and cities to generate even more precise areas for actions for urban planning through further developments, such as user group-specific catchment areas.

Especially with regard to the ageing society, it is becoming increasingly important to (re-)design UGS according to the needs and demands of the elderly, so that they can benefit from the ecosystem services of UGS. Our approach enables the inclusion of a qualitative component, thereby ensuring just access to the positive benefits of UGS for all citizens now and in the future.

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Supplementary materials

Suppl. material 1: Supplementary material 1 doi

Authors: Celina Stanley
Data type: table
Brief description: Overview of all UGS features, their indicators, the literature source for the calculation approach and the data source for calculating the indicators.
Download file (14.12 kb)

Suppl. material 2: Supplementary material 2 doi

Authors: Celina Stanley
Data type: Word document
Brief description: Questionnaire of survey 1.
Download file (14.39 kb)

Suppl. material 3: Supplementary material 3 doi

Authors: Celina Stanley
Data type: Word document
Brief description: Questionnaire of survey 2 (digital version); The analogous version was only available for ‘relaxing’, ‘eating & drinking’, ‘meeting friends’, ‘jogging’, ‘observing nature’ and ‘walking’.
Download file (16.78 kb)

Suppl. material 4: Supplementary material 4 doi

Authors: Celina Stanley, Sercan Cakir
Data type: Table
Brief description: Weighting factors (W_{FA}) of all features for the three activities divided into overall sample and elderly sample.
Download file (14.57 kb)

Suppl. material 5: Supplementary material 5 doi

Authors: Celina Stanley, Sercan Cakir
Data type: Table
Brief description: Weighted importance scores of all features of an activity () divided into overall sample and elderly sample.
Download file (14.64 kb)

Suppl. material 6: Supplementary material 6 doi

Authors: Sercan Cakir
Data type: Table
Brief description: Exemplary calculation of UGS quality scores including the raw and normalised UGS feature values for Beutler Park in the City of Dresden. The sub-indicators of Naturalness and Tranquillity each contribute half of the value of the feature (which is why they are multiplied by 0.5).
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Suppl. material 7: Supplementary material 7 doi

Authors: Celina Stanley, Sercan Cakir
Data type: Table
Brief description: Feature groups related to the activity ‘walking’.
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Suppl. material 8: Supplementary material 8 doi

Authors: Celina Stanley, Sercan Cakir
Data type: Table
Brief description: Feature groups related to the activity ‘relaxing’.
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Suppl. material 9: Supplementary material 9 doi

Authors: Celina Stanley, Sercan Cakir
Data type: Table
Brief description: Feature groups related to the activity ‘observing nature’.
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