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Assessment of Urban Quiet Areas in the Context of Nature-Based Solutions: Istanbul Historical Peninsula Example

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Abstract
It has been emphasised in previous studies that the definition of quiet areas, which are specified as areas to be identified and protected in the Environmental Noise Directive (END) in force for European Member States, cannot be reduced to 'the area below certain limit values for certain noise indicator values' and the positive effects of the presence of natural elements such as natural sounds, plants and aquatic environment on the perception of quiet areas. Therefore, this soundscape study examines not only the levels of sound, but also how sound sources, the acoustic environment, auditory perception, and personal interpretation interact in shaping our experience of a sound environment. This study investigates the potential of quiet areas to be included within the scope of nature-based solutions (NBS) through the example of Istanbul Historic Peninsula. In this study, data were collected from selected urban open and green spaces within the Istanbul Historic Peninsula through noise mapping, in situ sound recordings, and questionnaire-based surveys, all conducted in accordance with established soundscape standards. The collected data were analysed to explore the relationships between the sound environment and various physical environmental factors that influence the perception of quietness in urban settings. These relationships were further evaluated within the framework of nature-based solutions (NBS) strategies, with a particular focus on how such quiet areas can contribute to urban greening practices. Finally, the study discusses how insights gained from the soundscape analysis can inform space planning and design in urban contexts, emphasising the integration of acoustic quality in green infrastructure planning.

Keywords Nature-based solutions · Quiet areas · Soundscape · Istanbul historical peninsula

1 Introduction

Quiet areas in rural and agglomerations are defined as 'an area, delimited by the competent authority, for instance, which is not exposed to a value of Lden or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source' in the Environmental Noise Directive (2002/49/EC) implemented [1] by the European Parliament and the Council in 2002. In the same directive, it is stated that the 'limit value' should be determined by the member states, considering the principle of prevention for the protection of quiet areas in settlements. In addition, while preparing action plans for noise management, it is recommended that quiet areas in settlements with more than 250.000 inhabitants should be planned in a way to protect against noise increase. Accordingly, it is stated that the areas in urban areas that are below certain noise indicator values determined by the countries should be identified and these areas should be protected from noise. In this direction, in EU member states and in countries such as Türkiye, which is in the process of harmonisation with the EU, local governments generally carry out evaluation and determination studies as quiet areas for regions with a high likelihood of becoming quiet zones such as urban green areas, urban parks, pocket parks, water coasts, gardens, urban routes, cloisters in open land and settlements. Such urban open and green areas are also considered within the scope of urban forest, one of the NBS units type as a basic component in the grey—green–blue structural continuity of urban space [2]. This green infrastructure element, which is strategically planned and implemented in network structures in the urban context, plays an important role in urban planning processes in

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terms of its ecological functionality, qualitative development of public space and the benefits it provides to the user [3]. However, there is no consensus in Europe on the methodology used to identify these quiet areas, the assessment criteria and how to manage quiet areas. According to the report [4], which evaluates the implementation in Europe in line with the END, the fact that the factors for defining and determining quiet areas are not clearly stated, as in the determination of noise exposure, has led to implementation problems for the identification and protection of such areas. To address the problem of relying solely on sound-level measurements in urban acoustic research, soundscape studies have been undertaken to analyse not only the quantitative aspects of sound but also the complex interactions between sound sources, the acoustic environment, auditory perception, and interpretation involved in the experience of a sound environment [5]. Soundscape can be defined as the sound environment as it is perceived and understood by people in a given context [5]. In this way, soundscape studies on issues such as the definition [6, 7] and determination of quiet areas [8–15], what factors the perception of quietness depends on other than noise indicator values [16–21], environmental quality [22], the link between quiet areas and health and well-being [23] offer the opportunity to evaluate human perception in a more inclusive way together with other features of the natural and built environment. As a result of these researches, it was revealed that the determinants of quiet areas include dominant sound type, natural elements (such as plants, water, presence of natural sounds) [24–27], biodiversity [4, 28, 29], area dimensions [30], number of users [12], and historical value [31]. In addition, the tranquil characteristic of open and green areas within the scope of urban forests has been the subject of academic studies in the field of psychology in terms of contributing to restorativeness [32] and reducing stress [33], thereby raising life quality and contributing to the struggle of the urbanite/individual with complex urban challenges. In the fast-paced urban life with long working hours, spending time in quiet areas such as parks containing natural elements in urban areas is remarkable in terms of providing people with the opportunity to relax away from the busy and stressful urban life [32].

Especially in the studies examining the restorativeness, which is the property of contributing to mental renewal of quiet spaces [31, 34–36], the contribution of such areas to human health with their low noise levels and natural features is emphasised. In this direction, beyond the reduction of the concept of quiet area as an area below a certain limit value in a certain noise indicator, the question of whether it can be a unit and solution that can be evaluated within the scope of nature-based solutions (NBS) for the city and urbanites comes to mind. NBS, which was emphasised in the 2008 World Development Report titled *"Agriculture for Development."* and the first research programme was initiated in 2013, can be summarised as an approach that includes actions to benefit both the natural ecosystem and humanity in terms of social, economic and environmental aspects [37, 38] and to solve problems by taking inspiration from nature [39, 40] or making use of natural (or modified) elements. In this concept, it is aimed to maximise the benefit obtained by being inspired, supported or copied from nature in solutions to environmental, social and economic problems. NBS also include actions to protect, sustainably manage and restore natural or built habitats that provide benefits to human well-being and biodiversity [41]. Therefore, in this context, nature is both a benefactor and a beneficiary. Within the scope of sustainable development, it is recommended that nature-based solutions (NBS) rather than ecosystem-based approaches should be preferred to protect biodiversity and elevate human health and living standards [42].

Furthermore, the European Union's strategic frameworks, such as the Europe 2020 strategy promoting smart, sustainable, and inclusive growth, and the EU Thematic Strategy for the Urban Environment [43], underscore the central role of urban areas in integrating environmental, economic, and social dimensions of sustainable development. This recognition highlights the direct relevance of nature-based solutions (NBS) to land use and spatial planning practices [44]. Previous practices and case studies, despite their strengths and limitations, offer valuable insights for the planning, design, and implementation of nature-based solutions (NBS) in urban contexts, as well as for the subsequent evaluation and monitoring processes [45]. However, geographical conditions, cultural differences, and political dynamics suggest that each NBS initiative should be assessed within its unique context, even if the underlying principles are shared.

In this regard, the present study serves as a case example from Türkiye. It investigates the relationship between NBS and quiet areas by analysing data collected through fieldwork and noise mapping conducted across 16 open and green spaces within the urban forest framework of Istanbul historical peninsula. The study aims to explore the potential integration of quiet areas within the NBS framework.

2 Methodology

This research was designed as a soundscape case study, aiming to investigate the relationships between environmental noise levels, spatial characteristics, and users' perceptions of quietness in selected urban open and green spaces within the Historic Peninsula of Istanbul. A mixed-methods approach was adopted, integrating quantitative and qualitative data collection techniques, including transportation noise mapping, binaural sound recordings, and a questionnaire survey.

Noise mapping was conducted in accordance with the Environmental Noise Directive (END) [1] to assess the impact of transport-related noise across selected urban spaces of varying size, function, and spatial context. To complement the noise modelling data and evaluate the actual auditory environment, binaural sound recordings were carried out in situ. These recordings were analysed to determine ambient sound pressure levels and provide a basis for perceptual analysis, in line with the "ISO/TS 12913-2:2018 Acoustics—Soundscape—Part 2: Data Collection and Reporting Requirements" standard for data collection [46]. For the interpretation of perceptual soundscape data, the "ISO/TS 12913-3:2019 Acoustics—Soundscape—Part 3: Data analysis" standard was used [47].

In addition, a structured questionnaire was administered to users of the selected sites. Method A was selected for the survey on-site from ISO/TS 12913-2: 2018 standard due to its capacity to comprehensively address variables such as sound typology, the perception of quietness, and the assessment of environmental calmness, while also permitting the incorporation of non-acoustic factors relevant to the study's aims. Non-acoustic factors refer to variables that influence the perception, evaluation, or physiological response to sound, yet are not directly related to the physical properties of the sound itself [25]. The questionnaire aimed to capture perceptions of acoustic and non-acoustic characteristics of the spaces, including natural, modified, and built elements. Furthermore, it investigated the relationship between these characteristics and the perceived presence of "quiet" qualities in each location. All datasets were analysed through statistical correlation methods to explore the interrelations between physical noise measurements, environmental characteristics, and subjective user perceptions.

2.1 Noise Mapping

According to the Environmental Noise Directive, strategic noise maps for all agglomerations with more than 250.000 inhabitants for all major roads, major railways and major airports are expected to be prepared and renewed every 5 years in order to determine noise exposure [1]. In line with the Directive, 'areas below certain noise indicator values' are accepted as quiet areas with reference to the noise maps prepared. In this direction, to find out how far the urban open spaces in the delimited area are exposed to road and rail system noise, a noise map was prepared during daytime (from 07.00 to 19.00) using Soundplan 8.2, a programme that can make mapping in accordance with NMPB ROAD 96 for road and RMR 2002 standards for railway as required by the directive. Since there are no airports and industrial facilities within the area boundary, these noise factors were not factored in while preparing the map.

2.2 Binaural Sound Recordings

For the sound environment documentation, the sound walk method specified in ISO/TS 12913-2:2018 and defined as 'method that implies a walk in an area with a focus on listening to the acoustic environment' [46] was applied and sound recordings were taken during the sound walk by acoustic experts only, without a participant group. Within the designated areas, binaural recordings (together with calibration recordings) taken with binaural headphones connected to a portable recorder (B&K Type 2270-S Sound Level Meter/Analyser) calibrated using the sound walking method were analysed with Pulse Reflex software and sound pressure levels were calculated. The recordings were made on the routes determined to represent the sound environment in the area and with a maximum approach of 1.5 m to the sound sources (Fig. 1). While the length of the routes varied between 4 and 20 min, in the courtyard, which was too small to create a route, a minimum of 3 min point measurement was made in line with previous studies [30]. In accordance with ISO/TS 12913-2:2018, which emphasizes that sound recordings should be conducted during time periods that reflect the presence of relevant and typical sound sources within the acoustic environment [46], the field recordings were scheduled to capture representative acoustic conditions. Accordingly, binaural sound recordings were carried out during the summer months and in the afternoon hours, coinciding with peak usage periods of the urban open spaces and higher activity levels of dominant sound sources. This time frame was selected to ensure that the recorded soundscapes authentically reflected the characteristic acoustic environment of each site, thereby enhancing the validity of perceptual evaluations and environmental assessments.

LA5, LA10, LA90, LA95 A-weighted sound level exceeded at 5–10–90–50–95% of the measurement time were determined from sound pressure levels and calculated using the relevant sound recordings.

2.3 The Survey On-site

The questionnaire prepared in accordance with Method A [46], which is included in the ISO/TS 12913-2: 2018 standard to be applied in 16 selected areas and includes questions about how people perceive the acoustic environment in place, consists of 3 sections. Section 1 section presents general personal questions such as age, gender, educational status, occupation, hearing problem, Section 2 shows questions related to the perceived dominant sound type (traffic, other technological sounds, human, natural sounds), perceived affective quality (according to 8 adjectives-pleasant, chaotic, vibrant, uneventful, calm, annoying, eventful, monotonous) and general sound environment assessment (sound environment assessment, appropriateness, perceived noise) in the



Fig. 1 Examples of routes created for sound walking in the areas (from left to right Ahırkapı Park, Süleymaniye Mosque Garden, Eminönü Square)

type A questionnaire in the ISO/TS 12913-2:2018 standard [46], and Sect. 3 includes questions to evaluate how non-acoustic spatial features such as the amount of trees, water elements, historical and cultural value, cleanliness and maintenance, safety and accessibility are in the area.

A total of 480 people participated in the survey, 30 in each field. The surveys were carried out simultaneously with audio recordings at the points determined on the routes within the area, examples of which are given in Fig. 2. Data analysis for the perceived affective quality analysis of the areas was carried out using the formulas given in ISO/TS 12913-3:2019, while Spearman correlation analysis recommended in the standard was used to test the significance of the relationship between the data [47].

3 Data

3.1 Study Area

The Historic Peninsula of Istanbul, delineated by the ancient Byzantine walls, encompasses an area of approximately 16 square kilometres. This urban zone comprises a diverse mosaic of land uses, including residential neighbourhoods, commercial districts, touristic attractions, and areas of significant historical and cultural heritage, which together form a dynamic and layered urban fabric recognised as a UNESCO World Heritage Site. Within this culturally rich setting are various urban open and green spaces, such as large public parks, a coastal green belt, small neighbourhood parks, the gardens of historic buildings, and public squares. This spatial diversity contributes to the unique environmental, social, and visual character of the Peninsula, making it a key area for understanding complex urban dynamics. This study focuses on the Historic Peninsula due to its multifaceted land use pattern, historical significance, and the coexistence of densely built environments with open and green public spaces. The area's function as a living historical centre, simultaneously accommodating housing, commerce, tourism, and cultural activities, offers a valuable opportunity to investigate the interaction between heritage conservation, urban land use planning, and the provision of accessible green spaces. Such a setting provides important insights into the challenges and potentials of sustainable urban management in urban areas.

In this study, various typologies of urban open spaces, including large urban parks, pocket parks/gardens, heritage gardens, and urban squares were examined, all of which fall within the scope of nature-based solutions (NBS) units and also urban forests as defined in the literature [3, 48]. Following the identification of these spaces, each type was categorised based on its spatial scale, including classifications such as small-scale, neighbourhood-scale, district-scale, and city-scale parks. Subsequently, 16 urban open spaces with the largest surface areas and varying spatial characteristics (e.g. parks, gardens, squares, coastal areas) were selected for detailed fieldwork analysis (Fig. 2). Playgrounds and recreational areas smaller than 5000 m^2 were excluded from the scope of the study due to their limited spatial and functional capacity.

As a result of the observations made in the selected areas, the functional, natural and built characteristics of urban open and green areas were determined (Table 1). Three of the areas are urban parks (1–3), four are coastal parks (4–7), three are mosque gardens (8–10), three are squares (11–13), and three are special areas such as parks, courtyards and gardens in the historical environment (14–16).

4 Results

4.1 Transport Noise Exposure in Areas

According to the road and railway noise map prepared in Soundplan 8.2 programme by using data such as the average number of light and heavy vehicles passing per hour per year and average speed values and the number of railway vehicles passing during the daytime (07.00–19.00) and average speed values, the noise levels to which the open and green areas located at the points indicated by numbers are exposed are determined in dBA. According to the map, the places exposed

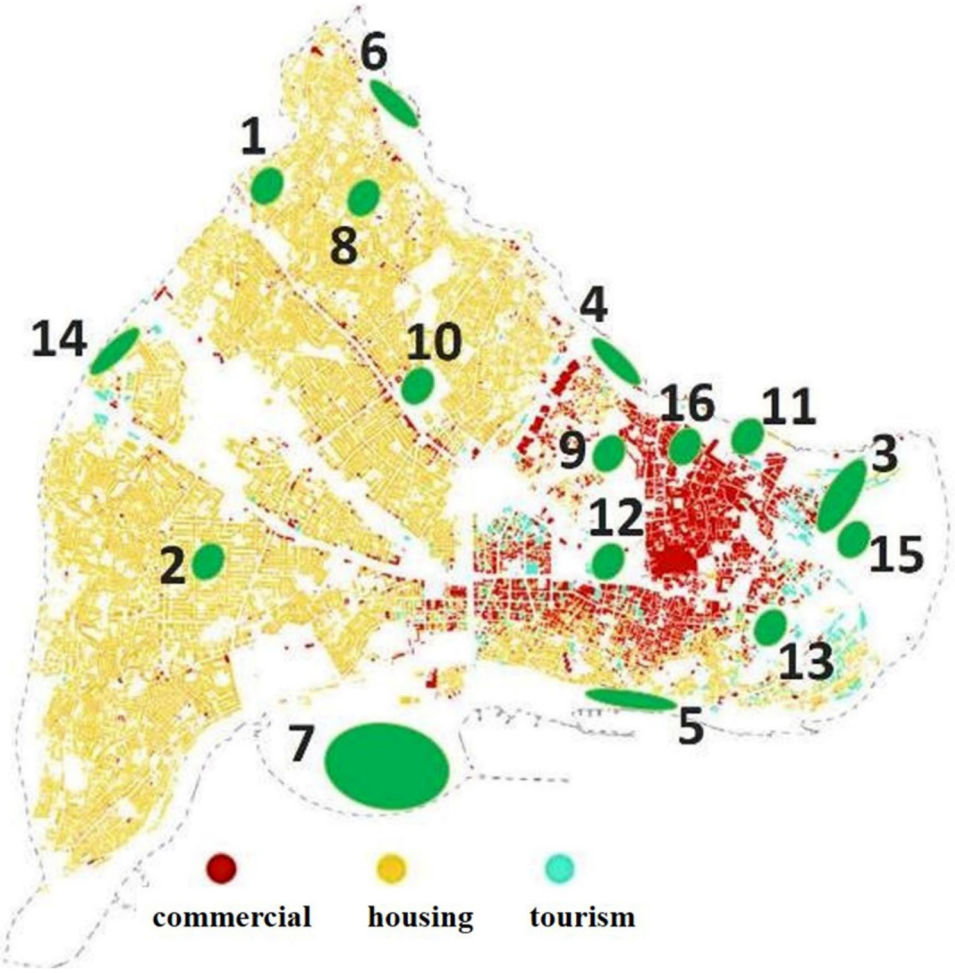


Fig. 2 The location of the open and green areas in the Historic Peninsula of Istanbul

to the highest transport noise levels are coastal parks (up to 70 dBA), then squares (up to 60 dBA), then mosque gardens and other parks located relatively far from the main roads (maximum 55 dBA) (Fig. 3). The situation in Gülhane Park, which was found to be exposed to a maximum of 55 dBA transport noise despite being located close to the coastal road, can be explained by the thick and high walls around the park acting as a noise barrier.

4.2 Sound Pressure Levels Calculated for the Areas

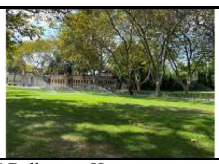
According to the results calculated by analysing the sound recordings and given in Table 2, LeqA values in the areas vary between 42 and 68 dBA, L5 values between 62 and 86 dBA, L10 values between 59 and 80 dBA, L50 values between 50 and 69 dBA, L90 values between 43 and 64 dBA, and L95 values between 41 and 63 dBA.

According to all noise indicator values, the areas with the highest sound levels are squares and coastal parks on the seashore, while the lowest levels are mosque gardens. According to the LeqA indicator, which is used as a noise indicator value in the regulations in force in Türkiye [49], areas above 60 dB (except Çukurbostan Park and Sultanahmet Square) are directly exposed to intense traffic noise.

The high noise level in Çukurbostan Park can be explained by the human voices arising from the multiple children's playgrounds and sports fields in the area. Sultanahmet Square, on the other hand, is a historical and touristic area with a high density of people, and the factor that increases the level is especially the sounds of crowded people. The reason for the high level in Fatih Mosque garden is due to the use of the area especially by immigrants for picnic and children's play purposes. Except for the special cases described, the sound level in areas that are not exposed to heavy traffic noise or surrounded by walls is below 55 dBA, which is the acceptable limit value in the Turkish regulation (Table 2). L95 values are below 60 dBA in all areas except Eminönü Square.

In coastal parks, the calculated equivalent continuous sound pressure levels accounting for all sound sources are largely consistent with the values represented in the transportation noise maps. However, in locations such as

Table 1 Photographs and features of the study areas

Area Name - Photo	Features	Area Name - Photo	Features
1.Kariye Park 	resting/ children's play activities rich vegetation water (pool) historical / cultural value	9.Süleymaniye Mosque 	resting /meditation/ touristy rich vegetation historical / cultural value wall/barrier
2.Fındıkzade-Çukurbostan Park 	resting/ children's play activities /spor rich vegetation	10.Fatih Mosque 	resting/ meditation/ children's play activities few trees historical / cultural value wall/barrier
3.Gülhane Park 	resting / touristy rich vegetation water (pool) historical / cultural value wall/barrier	11.Eminönü Square 	shopping/ touristy historical / cultural value
4.Haliç Coastal Park 	resting few trees water (sea)	12.Beyazıt Square 	shopping few trees historical / cultural value
5.Ahırkapı Coastal Park 	resting/ children's play activities plants and trees water (sea)	13. Sultanahmet Square 	touristy few trees historical / cultural value
6.Akşemseddin Coastal Park 	resting plants and trees water (sea)	8.Topkapı Park 	resting rich vegetation historical / cultural value wall/barrier
7.Yenikapı Coastal Park	resting rich vegetation water (sea)	15.Topkapı Palace Garden	resting / touristy rich vegetation historical / cultural value wall/barrier
			
8.Yavuz Selim Mosque 	resting/ meditation rich vegetation historical / cultural value wall/barrier	16.Balkapanı Han 	warehouse / shopping saksı bitkileri/sarmaşık historical / cultural value wall/barrier

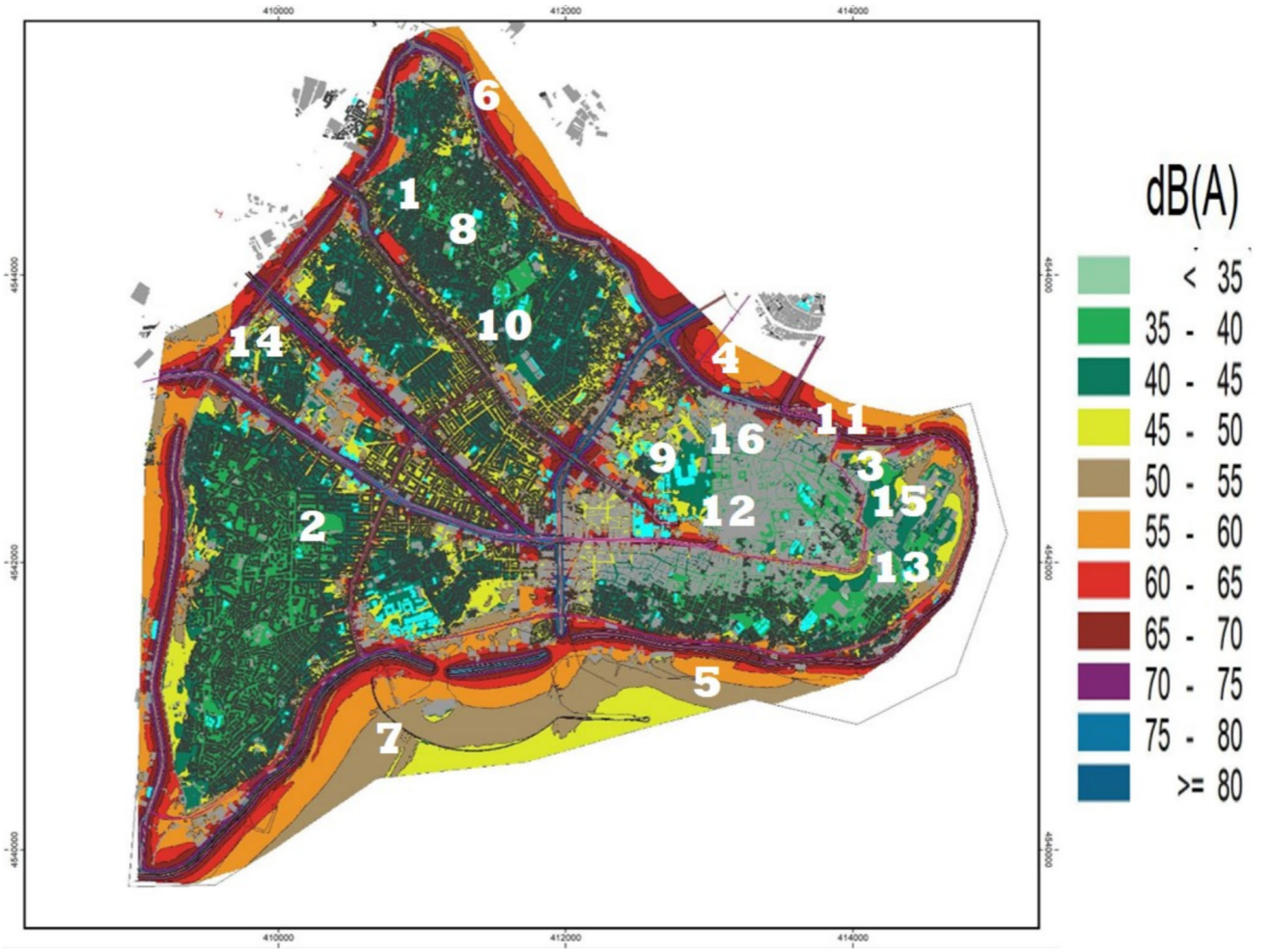


Fig. 3 Istanbul Historic Peninsula Lday transport noise map

Table 2 Calculated sound levels for the areas (dBA)

Areas	Leq	L5	L10	L50	L90	L95
1.Kariye Park	53,46	67,82	66,39	60,40	52,85	50,51
2-Çukurbostan Park	60,94	75,72	72,77	67,86	60,29	59,16
3-Gülhane Park	60,88	66,27	64,44	59,40	55,84	55,16
4.Haliç Sahil Park	68,00	74,64	71,45	63,53	59,64	59,09
5.Ahırkapı Coastal Park	62,47	74,96	70,32	59,69	53,69	52,34
6.Akşemseddin Coastal Park	60,33	74,43	69,59	60,23	54,74	53,29
7. Yenikapı Coastal Park	59,00	76,64	73,92	63,38	57,32	56,36
8.Yavuz Selim Mosque	42,09	69,05	63,56	50,23	43,07	41,73
9. Süleymaniye Mosque	47,63	69,38	65,19	56,10	49,37	47,73
10.Fatih Mosque	62,32	68,78	66,36	58,95	51,22	49,61
11.Eminönü Square	68,22	86,53	80,40	69,83	64,16	63,40
12. Beyazıt Square	61,30	78,37	73,04	64,00	59,41	58,52
13.Sultanahmet Square	62,37	76,37	73,04	62,45	58,14	57,36
14.Topkapı Park	64,10	67,38	65,20	59,04	54,47	53,21
15.Topkapı Palace	55,91	64,55	61,95	56,37	52,86	51,82
16.Balkapanı Han	52,06	62,44	59,63	52,92	50,93	50,57

Çukurbostan Park, Gülhane Park, Fatih Mosque, Sultanahmet Square, and Balkapanı Han, the measured sound levels exceed those indicated on the noise maps. This discrepancy can be attributed to the high population density in these areas and the fact that the sound measurements were conducted during peak periods of human activity.

4.3 Perceived Affective Quality Analysis

The data on perceived affective quality from the surveys conducted in the field studies can be reported in a scatter plot with two main axes (pleasantness and eventfulness) and two intermediate axes (calmness and vibrancy). Each data point in the scatter plot represents an area under investigation. This evaluation was carried out in order to reveal how the sound environment in the areas is evaluated according to 8 adjectives (pleasant, chaotic, eventful, uneventful, calm, annoying, eventful, monotonous) [47]. Accordingly, the approach of an area to the calm axis can be evaluated in the sense that it has a high potential to be a quiet area. The data collected as a result of the surveys conducted in 16 different areas selected from the area bounded by the Historic Peninsula of Istanbul were analysed, and the locations of the areas on the scatter plot were determined by making the necessary calculations (Fig. 4).

When we look at the distribution of 'how' the areas are perceived by the users in terms of sound environment in total on the graph, it is seen that certain areas are gathered around certain axes. These evaluation results made by the users were interpreted in line with the observations made in the field.

1. The areas gathered around the calm axis are Yenikapı Coastal Park, Yavuz Selim Mosque, Topkapı Palace Garden, Gülhane Park, Süleymaniye Mosque, Haliç Coastal Park, Akşemseddin Coastal Park, Topkapı Park and Balkapanı Han. The common feature of these areas is not that they have low sound pressure levels. The seafront parks were evaluated as calm by the users even though they were exposed to traffic noise. This shows that natural elements such as water and plants are very effective in the perception of quiet spaces. The areas other than the coastal parks are noteworthy for having natural elements such as trees, grass and potted plants as well as historical and cultural values.
2. The areas centred around the pleasant axis are Kariye Park, Ahırkapı Coastal Park, Beyazıt Square and Sultanahmet Square. In these areas, historical texture, mature trees and the sea come to the fore. However, the difference from other areas considered as calm is that there are children's playgrounds in the parks and there is a density of tourists in the squares.
3. The areas gathered around the vibrant axis are Fatih Mosque and Fındıkzade Çukurbostan Park. The most prominent feature of these areas is the presence of children's play function and sports fields.
4. Eminönü Square is located around the eventful axis. Eminönü Square, which is considered as eventful, is exposed to traffic noise and intense human voices and is the poorest area in terms of natural elements such as trees and plants.

4.4 Relationships Between Acoustic and Non-acoustic Factors Affecting the Perception of Quiet Space

By correlating the dominant sound type, spatial characteristics and calculated sound pressure levels with the answers given to the survey questions, respectively, the relationship between acoustic factors as sound type, sound level [10–16] and non-acoustic factors as natural element (green and blue), historical and cultural value, cleaning and maintenance, security, accessibility [8–12, 16, 24, 30, 31] that are effective in the perception of urban open spaces as quiet areas was analysed and an idea was tried to be obtained about which features are more effective in the perception of quiet areas.

4.4.1 Relationship of Dominant Sound Type to Other Sound Types, Perceived Affective Quality and General Sound Environment Assessment

The sound type classification used in this study is based on ISO 12913-2:2018 Method A[46], and the sound types are divided into 4 types as traffic sounds, other technological sounds, human sounds and natural sounds. The dominance of traffic sounds has an inverse relationship with the perception of the sound environment in the area as pleasant, calm and uneventful; while it has the same directional relationship with the perception of annoying, chaotic, eventful and vibrant. The predominance of other technological sounds and human voices is largely parallel to traffic sounds (Table 3). It is seen that the dominance of natural sounds has a significant effect in the opposite direction of the other three sound types. According to the results, there is a linear relationship between the perception of natural sounds as dominant and the perception of the areas as pleasant, uneventful and calm. In addition, in areas where natural sounds are perceived as dominant, the sound environment is evaluated as good and appropriate, while the perceived noise is reduced.

4.4.2 Relationship of Spatial Characteristics with Dominant Sound Type, Perceived Affective Quality and General Sound Environment Evaluation

While there is a significant relationship between the positive evaluation of spatial features such as green texture, historical

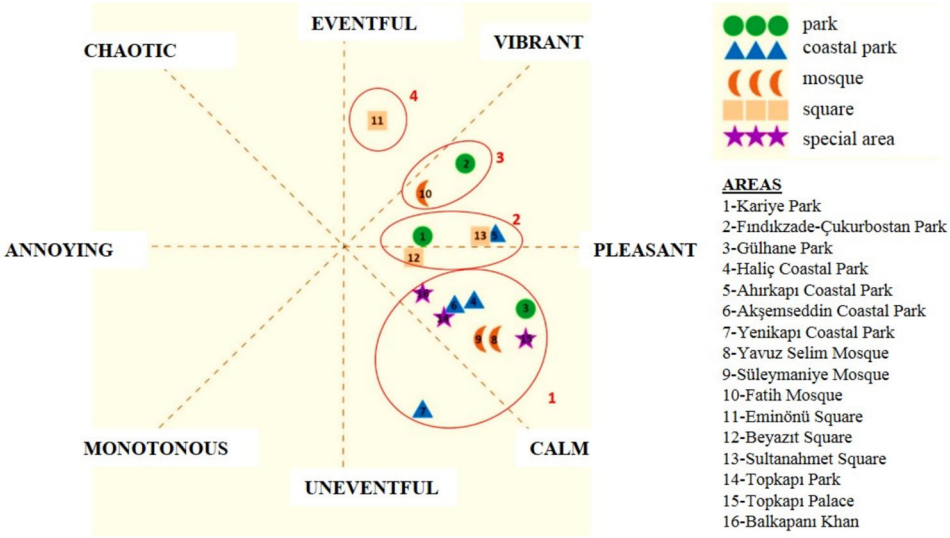


Fig. 4 Evaluation of workspaces in terms of perceived affective quality

and cultural value, cleanliness and maintenance, safety and accessibility and the perception of natural sounds as dominant, the perception of the sound environment as pleasing, uneventful and calm, and the evaluation of the sound environment as good and appropriate, there is an inverse relationship with the dominance of traffic and other technological sounds. Among the spatial features, the weakest relationship with the perceived sound environment was found between historical and cultural value, while the strongest relationship was found with green texture. The areas where the green texture is evaluated as good by the user are perceived as pleasant, uneventful and calm areas where natural sounds are dominant. An important reverse relationship can be observed between green texture and the dominance of other types of technological sounds and perceived noise. Areas dominated by traffic and other technological noises are perceived as worse in terms of cleanliness, maintenance, safety and accessibility. In addition, in areas where natural sounds are dominant, the sound environment is pleasant, uneventful and calm in terms of perceived affective quality, and in areas that are evaluated as good, appropriate and noise-free in the general sound environment evaluation, such spatial characteristics are also evaluated as good (Table 4).

4.4.3 Relationship of Sound Levels with Dominant Sound Type, Perceived Affective Quality and General Sound Environment Assessment

When the perceived acoustic condition and acoustic measurement results were correlated, as expected, a significant inverse relationship was found between the measured LeqA values and the perception of the areas as calm and monotonous, and the same directional relationship was found with the perception of eventful and noisy. However, an important inverse relationship exists between L50, L90 and L95 and the perception of the sound environment in the areas as monotonous. Surprisingly, no meaningful correlation was found between the measured acoustic values and the dominant sound type and pleasantness (Table 5).

5 Discussion

As in previous studies, the outcomes of this study indicated that the perception of quiet space does not depend only on the sound pressure level [50], and that other noise sources (transport-industry) other than the noise sources considered in line with END, such as human voices, also negatively affect the perception of quiet space, while historical and cultural heritage in the areas have a positive effect [31]. In addition, it has been revealed once again that the feature that is significantly associated with the perception of quiet space and stands out with its positive effect is the auditory and visual natural components [51, 52]. In fact, among the open spaces examined in the study, it was observed that the places exposed to intense traffic noise (up to 70 dBA) and where the measured sound pressure value was up to 77 dBA (L5) were evaluated as 'quiet' by the users. The crucial feature of this area is that it is located on the seafront, most of the area is covered with grass and trees, and is therefore surrounded by natural elements in visual and auditory terms [53, 54]. With these elements [24, 30, 55–57], quiet spaces contribute to the health and well-being of their users [58]. Previous studies show that typical sounds of nature and restorative qualities are often attributed to sound environments over those in the built environment, reiterating the separation between natural and built visual–spatial landscapes [59]. Therefore, in line

Table 3 The relationship between perceived affective quality and perceived dominant sound type for workspaces

		Types of sound sources			
		Traffic sounds	Other technological sounds	Sounds from human beings	Natural sounds
Sound source identification	Traffic sounds	1.000	.551**	.283**	− .173**
	Other technological sounds	.551**	1.000	.296**	− .231**
	Sounds from human beings	.283**	.296**	1.000	− .133**
	Natural sounds	− .173**	− .231**	− .133**	1.000
Perceived affective quality	Pleasant	− .336**	− .392**	− .331**	.409**
	Chaotic	.150**	.126**	.288**	− .100*
	Vibrant	.120**	.016	.298**	− .148**
	Uneventful	− .191**	− .265**	− .364**	.196**
	Calm	− .299**	− .354**	− .481**	.272**
	Annoying	.208**	.319**	.296**	− .235**
	Eventful	.184**	.176**	.389**	− .141**
	Monotonous	− .037	− .041	− .151**	.076
General sound assessment	Surrounding sound environment	− .376**	− .463**	− .372**	.393**
	Appropriateness	− .335**	− .383**	− .268**	.326**
	Perceived noise	.371**	.423**	.538**	− .366**

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)
*$p < 0.05$; **$p < 0.01$

Table 4 The relationship between acoustic perception and perceived spatial characteristics for workspaces

		green	water	historical and cultural value	cleaning and maintenance	security	accessibility
sound source identification	traffic sounds	-,183**	-,183**	-,113*	-,335**	-,311**	-,125**
	other technological sounds	-,399**	-,399**	-,045	-,370**	-,294**	-,216**
	sounds from human beings	-,108*	-,108*	-,024	-,127**	-,081	,013
	natural sounds	,179**	,179**	,100*	,216**	,117*	,148**
perceived affective quality	pleasant	,318**	,318**	,179**	,349**	,330**	,242**
	chaotic	-,042	-,042	,039	-,102*	-,061	,042
	vibrant	,056	,056	,087	-,041	,038	,108*
	uneventful	,197**	,197**	,107*	,238**	,171**	,190**
	calm	,233**	,233**	,081	,260**	,257**	,166**
	annoying	-,281**	-,281**	-,036	-,291**	-,299**	-,112*
	eventful	-,015	-,015	,095*	-,037	-,008	,020
	monotonous	,036	,036	,003	,059	,020	,084
general sound assesment	surrounding sound environment	,287**	,287**	,184**	,442**	,405**	,206**
	appropriateness	,304**	,304**	,232**	,428**	,375**	,335**
	perceived noise	-,234**	-,234**	-,102*	-,370**	-,295**	-,158**

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)
*$p < 0.05$; **$p < 0.01$

with NBS, there is a contribution to human health and well-being by utilising nature in quiet spaces.

The existence of quiet areas provides a good acoustic environment not only for the people using it, but also for other living things in the area. With the expansion of such areas in cities, more living space will be created for plants and animals living in such areas. Therefore, quiet areas also benefit nature. Open and green quiet areas have positive effects on urban acoustics in the whole city. The distribution of such areas in the city can contribute to noise reduction not only for physical reasons, but also indirectly due to settlement density and restriction of vehicle use [60].

Open and green spaces such as parks [61, 62], courtyards [63, 64] and gardens [53] are generally considered as areas with the potential to be quiet spaces in urban areas. At the same time, green spaces, gardens and parks are considered as essential NBS to create more livable, healthy and resilient cities [65]. NBS spatial units such as green corridor, large urban park, pocket/garden park, urban meadows, green transition zones [66], which are also included in the scope of urban forest [67], have been investigated in the context of NBS in various aspects such as improving environmental quality [68], health and well-being [3, 69–71], blue/green infrastructure [72], urban biodiversity, green spaces and stress [3, 73]. In more than 500 NBS case studies analysed, it was found that half of the subjects were urban and riverine areas and green approaches were used [45]. Urban forestry is an effective field of study for the implementation of NBS in urban areas [67, 73] and achieving its goals [3, 67, 74]. In this context, both quiet areas and urban forests, which are considered within the scope of NBS, can help improve people's physical and mental conditions through the healing effects of green [75]. This can indirectly contribute to the economy by helping to increase labour productivity in people. Moreover, it has been revealed that green areas provide many benefits such as improvement

Table 5 The relationship between acoustic perception and sound levels for workspaces

		Leq	L5	L10	L50	L90	L95
sound source identification	traffic sounds	,480	,297	,296	,315	,296	,321
	other technological sounds	,447	,187	,202	,233	,206	,242
	sounds from human beings	,462	,209	,309	,353	,188	,150
	natural sounds	-,419	-,222	-,244	-,318	-,375	-,425
perceived affective quality	pleasant	-,415	-,324	-,344	-,350	-,256	-,276
	chaotic	,169	,224	,225	,279	,111	,069
	vibrant	,456	,201	,285	,345	,285	,258
	uneventful	-,515*	-,365	-,405	-,468	-,331	-,315
	calm	-,582*	-,412	-,456	-,450	-,368	-,359
	annoying	,234	,258	,312	,362	,234	,249
	eventful	,553*	,263	,365	,472	,378	,349
	monotonous	-,556*	-,451	-,473	-,556*	-,582*	-,536*
general sound assesment	surrounding sound environment	-,466	-,315	-,367	-,405	-,295	-,311
	appropriateness	-,436	-,181	-,208	-,199	-,149	-,168
	perceived noise	,563*	,277	,323	,385	,361	,376

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)
*$p < 0.05$; **$p < 0.01$

of various diseases such as obesity, cancer, asthma, reduction in air and noise pollution, socialisation, prevention of overheating and cooling [69].

In line with the previous studies and the findings of these studies, it is revealed that there are many commonalities between the definition, scope and benefits of NBS and the characteristics and benefits that define the quiet areas in the city. These commonalities are summarised in Table 6.

In line with the recognised significance of green infrastructure in the provision and preservation of quiet areas, it is recommended that:

- Such areas be classified as nature-based solutions (NBS), or more specifically as Urban Forest Nature-Based Solutions (UF-NBS), and be managed by local authorities under the designation of 'specialised urban green spaces';
- The integration and/or enhancement of natural features such as trees, vegetation, and water features be prioritised to strengthen the ecological and acoustic quality of these spaces;
- Quiet areas be protected from external noise sources through the implementation of physical noise barriers or bio-acoustic barriers (e.g. vegetative buffers);
- A hybrid approach combining green and blue infrastructure be pursued where feasible—particularly by evaluating and managing natural water edges as potential quiet zones, and by planning and constructing artificial water features in areas lacking such natural components;
- The spatial distribution of quiet areas be considered within urban planning processes, ensuring equitable accessibility by taking into account population density and land-use characteristics, and locating such areas within a walkable distance from residential zones;
- The potential of historically and culturally significant sites for the establishment of quiet spaces be explored, incorporating green elements into their design to enhance their restorative qualities;
- Activities that may compromise the acoustic environment such as children's play, sporting events, and high-intensity tourism, be restricted within designated quiet areas;
- The usage intensity of quiet areas be systematically monitored to inform future management strategies and avoid overcrowding;
- The pedestrianisation of surrounding streets and pathways be pursued where applicable, to enhance both the acoustic and environmental quality of quiet areas.

6 Conclusion

The findings of this study indicate that reducing the levels of certain urban noise sources to specific thresholds is not a sufficient strategy to ensure public health and well-being. This is because it has been demonstrated that the perception of quietness may be more strongly correlated with natural elements

Table 6 Common characteristics of NBS and quiet areas

Nature based solutions	Quiet area
Benefit from nature [37, 38]	Plants, water element, other living things contribute to the perception of quiet space both visually and audibly [24, 30, 55–57]
Benefit to nature [37, 38]	Contributing to noise reduction [60, 76] Protection of other living beings in nature from noise in quiet areas
Solutions to environmental problems	Contributing to noise reduction Creating noise-protected environments [60]
Solutions to policy problems	The need for an alternative approach to the failures in quiet zone management, which are addressed within the scope of environmental noise management [77]
Solutions to economic problems	Contributes to the reduction of labour and material effort spent on noise control [60] Increased labour productivity through mental renewal in quiet areas [78–80]
Solutions to social problems	The possibility of socialising in quiet areas
UF-NBS Urban forests as nature-based solutions [3, 67]	High potential of open green areas to be quiet areas [55, 61, 62]
NBS UNITS-Green built environment: Urban parks, forests, street trees, gardens, green corridors, pocket parks… [39, 40, 66, 81]	High potential of open green areas to be quiet areas [55, 61, 62]
NBS UNITS -Blue-green space creation: [71]	The positive contribution of the presence of both plants and water to the perception of quiet space [78, 79]
Green solutions: Urban parks, Heritage Park, Green strips, Plains grass cover, Trees and shrubs, Forest orchard, Hedges/shrubs/green fences, Street tree(s), etc. [45, 66]	The positive contribution of green areas and the amount and diversity of greenery in these areas to noise reduction, reduction of noise disturbance and perception of quiet areas [82]
Blue Solutions: Ponds, Wetlands, Rivers, Lakes and streams, Seas and oceans, Aquifer protection, Room for the river, Constructed flood storages, etc. [45]	The positive contribution of the use of water element to the perception of quiet space [78, 79]
Cultural heritage [45]	Quiet areas should also be considered within the scope of protection The positive contribution of the presence of historical and cultural heritage elements to the perception of quiet space [31, 63, 64]
Health and wellbeing, quality of life [69, 70, 81]	Quiet areas contribute to stress reduction and restorativeness, increasing quality of life [31, 34–36, 82–85]

such as vegetation and water features than with objective sound pressure levels. It is evident that urban quiet areas cannot be defined solely by absolute low sound levels; rather, the presence of natural elements positively influences the perception of tranquillity. Therefore, while efforts to reduce urban noise levels continue, it is essential to develop an approach that involves the identification, utilisation, and conservation of urban open spaces supported by natural components such as urban forests in order to address the need for quiet areas and to promote psychological restoration and stress reduction among urban residents. As a solution to the challenges encountered in defining, identifying, and preserving quiet areas in accordance with the Environmental Noise Directive (END), it is proposed that quiet areas be conceptualised as green infrastructure units that both deliver and receive benefits within the framework of nature-based solutions (NBS), and that they be planned and managed accordingly.

In this way, the problem of uncertainty and other managerial problems that arise within the scope of environmental noise management on the subject of quiet areas can be maximised by limiting the framework of quiet areas more clearly in the context of NBS and clarifying the context in which they will be handled, and the benefits to nature and humanity can be maximised. Because it is known that urban green spaces are not only beneficial not only in terms of providing silence and reducing noise, but also in other environmental issues such as thermal comfort and air quality. Therefore, when the concept of quiet space is added to the mission of urban green spaces in the city, it can contribute to the design of more sustainable and resilient cities in terms of nature and health. In order to maximise this contribution, it is recommended that different disciplines come together, sample studies should be increased by taking into account cultural and local differences in social life and perception, and the study areas should be diversified in different geographies, not limited to Europe. The data to be obtained from these sample studies can help both researchers and policy-makers to develop a road map for the identification, determination, planning and use of quiet areas within the scope of NBS and

can support urban forests to combat climatic problems and other pollution problems in a stronger way.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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