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Characterisation of the soundscape of parks and green areas through the triangulation of methodologies proposed by ISO/TS 12913-2

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SUMMARY

The management of urban spaces and environmental health has been growing in recent years, and the sound aspects were highlighted during the Coronavirus pandemic (COVID-19). Locations that generally showed noises from vehicle traffic presented a diversity of sounds, generally not perceived in everyday situations before the pandemic. Awareness of the sound impacts generated before the pandemic has provided a broad discussion between the scientific community and managers regarding developing tools to improve urban planning and environmental health in cities. This study aims to characterise the soundscape of two parks in Curitiba by triangulating evaluation methodologies proposed in the ISO/TS 12913-2 (2018). Such triangulation included the descriptive analysis of objective and subjective sound data, analysis and elaboration of sound and perception maps, providing a systemic overview of the sonic environment of the investigated parks.

KEYWORDS: Soundscape. Triangulation of methodologies. Parks and green areas.

1. INTRODUCTION

In recent years, there has been a significant trend of population change from rural to urban areas; consequently, there has been a growing concentration of inhabitants in cities (GOZALO; MORILLA; GONZÁLEZ; MORAGA, 2018). As population growth and urbanisation are the leading causes of the continuous increase in noise exposure, excessive noise exposure has become a challenge to the health and well-being of the population (SCHWELA, 2021). Noise is a significant agent of environmental degradation in cities, as it negatively influences human health and the population's quality of life (HIRASHIMA; MOTA; ASSIS, 2019).

Exposure to environmental noise is responsible for several health effects. It includes an increased risk of heart disease, sleep disorders, cognitive impairment among children, mental health risks related to stress and tinnitus, with road traffic being the leading cause of noise in most cities (WHO, 2021). One of the biggest challenges for cities today is harmonising urban development and conserving natural resources, as these suffer impacts caused by the imbalance between development and conservation. In this context, urban green areas can play an essential role in the quality of life of their population (ARAÚJO JÚNIOR; SANTOS; PEREIRA; OLIVEIRA, 2018).

Green areas play a balancing role between the modified space and the environment. They are also used to assess urban environmental quality. Therefore they are fundamental for the environmental quality of cities (ARANA; SIQUEIRA; ULIANA; RODRIGUES; CAMARA; NOGUEIRA, 2020). Among the green areas, urban parks are considered essential public areas for sustainable urban environments (JASZCZAK; POCHODYŁA, 2021). These areas provide the best harmony and approximation of the inhabitants with the environment, thus allowing a meeting area, walkability, contact with nature, leisure, physical activities, improving physical and mental health, and providing social and environmental improvements to life in cities (ARAÚJO JÚNIOR; SANTOS; PEREIRA; OLIVEIRA, 2018). Parks are considered quiet areas with restorative effects. However, their environmental and social functions, involving improving the urban environment's soundscape through noise reduction, may be restricted by their size and location (WATTS; PHEASANT; HOROSHINKOV, 2010).

The proper environmental conditions of parks have a decisive effect on their use and also on their benefits, and can promote the health and well-being of patrons. However, the poor environmental quality and dissatisfaction of patrons are negative effects for the use of these environments, can mischaracterise the environmental, social and public health benefits and functions (SZEREMETA; ZANNIN, 2013, ARAÚJO JÚNIOR; SANTOS; PEREIRA; OLIVEIRA, 2018). Dissatisfaction with the environment does not only affect the experience but also their willingness to attend. Consequently, the benefits of urban parks are harmed due to poor environmental quality (MA; MAK; WONG, 2021).

In the past, 'designers' tended to consider only visual landscapes in landscape construction and ignore the importance of the population's auditory perception, which could negatively affect people's health (FAN; FE; HU, 2021). Therefore, the concept of soundscapes emerged, focusing on people's sound perception (KANG; SCHULTE-FORTKAMP, 2015). Between the 60s and 70s, R. Murray Schafer first proposed the concept of soundscape (SCHAFER, 1977, FAN; FE; HU, 2021). For the author, a soundscape is an example of a soundscape considered a field of research. In other words, a soundscape means the entire soundscape, including all environmental sounds, as well as all sounds in our daily life, whether they are pleasant or unpleasant (SCHAFER, 1977).

In environmental acoustic research, the term "sound landscape" is recognised as the acoustic environment of a place, perceived, or experienced by people in its context, resulting from the action and interaction of natural and/or human factors (ISO 12913-1, 2014). The study of soundscape thus means a paradigm shift from noise control policies to a new multidisciplinary approach that involves not only physical measurements but also the diversity of sounds from different cultures and regions, with a focus on the sound perception of people (KANG; ALETTA; GJESTLAND; BROWN; BOTTELDOOREN; SCHULTE-FORTKAMP; LERCHER; VAN KAMP; GENUIT; FIEBIG; BENTO COELHO; MAFFEI; LAVIA, 2016). Thus, helping to create a healthy and comfortable environment for individuals, providing a sound quality experience, considering sound as a resource and not a waste (KANG; ALETTA; GJESTLAND; BROWN; BOTTELDOOREN; SCHULTE-FORTKAMP; LERCHER; VAN KAMP; GENUIT; FIEBIG; BENTO COELHO; MAFFEI; LAVIA, 2016, BROWN, 2012).

Different techniques can be used to assess the soundscape of parks, helping to verify the sound quality and impacts of environmental noise, including sound maps and sound perception maps. Sound maps are widely used to assess exposure to unwanted sounds (noise) and sound perception maps provide visual representations of perceptual properties related to the sound environment (ALETTA; KANG, 2015).

The urban soundscape gained notoriety because of the pandemic caused by the Coronavirus (COVID-19). With restrictions on urban mobility, traffic noise was drastically reduced. Thus, anthropogenic activities directly cause the urban soundscape (ASENSIO; AUMOND; CAN; GASCÓ; LERCHER; WUNDERLI; LICITRA, 2020; DROUMEVA, 2021). Therefore, this is the time to give due importance and search for new measures to assess the sound quality in urban spaces. Therefore, this study aims to highlight the importance of urban green areas for the health of the population and the visual and sound quality to realise the benefits of this environment, to justify the relevance of research on the environmental quality of urban green areas.

2. OBJECTIVES

This study aims to characterise the soundscape of two parks in Curitiba, with distinct characteristics. The method of triangulation of methodologies proposed in ISO/TS 12913-2 (2018) was used to achieve this objective, to systematically address physical aspects (sound sources, physical media, sound propagation) and subjective aspects (answers of sound perception). The methodological triangulation will consist of descriptive analysis of objective and subjective data, sound mapping and sound perception of the studied areas.

3. METHODOLOGY

This study is based on empirical data obtained from the doctoral thesis of Szeremeta (2012), who collected sound data through sound pressure level measurements, subjective data through interviews in parks in Curitiba and sound pressure level simulations through sound mapping.

As a methodological basis, the recommendation of methodological triangulation established by ISO/TS 12913-2 (2018) was followed, combining methods for evaluating the soundscape. The triangulation performed in this study used empirical data from Szeremeta (2012) in the following formulation: 1) Descriptive analysis of subjective (sound perception) and objective (sound pressure levels) data; 2) sound mapping analysis; 3) elaboration and analysis of sound perception maps.

As described in the doctoral thesis of Szeremeta (2012), sound pressure levels were collected for 15 minutes between 5 pm and 7 pm at seven points at General Iberê de Mattos Park (Bacacheri Park) and nine points at the Botanical Garden. The simulation of sound pressure levels was performed with the software Predictor version 6.2 from BRÜEL and KJAER, where the sound propagation calculation method ISO 9613-2 (1996) was used for linear sound sources, such as vehicle traffic. The 3D simulation of the buildings was based on satellite images from Google Earth (2010). The standardisation of the heights of the buildings was carried out as follows: standard: medium and large houses equal (=) to 3 and 4 meters, respectively; houses = 6 meters; small, medium, and large sheds = 6, 10 and 12 meters, in this order and buildings = 3 meters for each floor.

3.1. Study areas

The study was carried out in two green areas, Botanical Garden and General Iberê de Mattos Park (Bacacheri Park), both located in the city of Curitiba (Figure 1). Curitiba is the capital of Paraná, one of the three states that make up the southern region of Brazil. Its official foundation dates from March 29, 1693, located at 25º25'48'' south latitude and 49º16'15'' west longitude of the Greenwich Mean Time. It has an area of 434.892 km², and the estimated population is approximately 1.9 million people (IBGE, 2020). Curitiba has one of the best green areas in the country, 52 square meters per inhabitant, totalling about 82 million m². The city of

Curitiba has 30 parks and forests (PMC, 2021), which makes data collection in these locations unfeasible. Therefore, two parks in the city were chosen, the Botanical Garden located very close and practically surrounded by heavy vehicular traffic, and Bacacheri Park located further away from these roads, in a region considered quieter. Therefore, by comparing these two categories of contexts. It will be possible to assess the influence of the surrounding urban form on the environmental sound of these areas.

Figure 1: Study areas

Source: SZEREMETA, 2012.

3.2. Sound perception maps

Sound perception maps were simulated in ArcGIS Pro using the Geostatistical method of "Ordinary Kriging". The prediction is calculated based on known coordinates of the sample, linearly, with the inverse distance weighting technique. The model used is Gaussian, so the samples must have a normal distribution. The prediction distribution is estimated through standard deviation or variance to find the variance, the Semivariogram. It predicts the distance from a given point and the one to be simulated (LADIM, 2006).

The data used to simulate the sound perception maps were obtained from two interview questions conducted by Szeremeta (2012) with users in Bacacheri Park and Botanical Garden in Curitiba. 82 people were interviewed in each of the parks.

The sound perception questions about the parks were elaborated as follows:

1) During your visit, how often did you hear the following categories of sounds?

a) Human sounds (people talking, children playing, etc.);

b) Natural sounds (song of birds, the sound of wind in the leaves of trees, sounds coming from the water, etc.);

c) Mechanical sounds (traffic noise, planes, machines, etc.). Each sound category was evaluated with the following possible answers: 1 = I didn't hear anything, 2 = very little, 3 = little, 4 = a lot, 5 = all the time.

2) How do you perceive the ambient sound in this park? (Listen to the surrounding park sound for 20 seconds before answering)

a) Pleasant (1 = very pleasant, 2 = pleasant, 3 = unpleasant, 4 = very unpleasant);
b) Agitation (1 = very agitated, 2 = agitated, 3 = calm, 4 = very calm);
c) Excitement (1 = very exciting, 2 = exciting, 3 = monotonous, 4 = very monotonous);
d) Intensity (1 = very quiet, 2 = quiet, 3 = noisy, 4 = very noisy).

4. RESULTS

As described in item 3 (Methodology), the results of the descriptive analysis of objective (sound pressure levels) and subjective (sound perception responses) (item 4.1) from two parks in Curitiba will be presented below. The sound maps (item 4.2) and sound perception maps (item 4.3) will also be presented, thus composing the methodological triangulation to evaluate the soundscape of the investigated areas.

4.1. Descriptive analysis of objective and subjective data

Sound measurements took place at seven points in Bacacheri Park and at nine points in Botanical Garden (Table 1). The maximum sound pressure levels (LAmax) ranged from 69 to 78 dB(A) in Bacacheri Park (PB) and 74 to 90 dB(A) in Botanical Garden (JDB). Equivalent sound pressure levels (LAeq) range from 52 to 58 dB(A) in PB and 54 to 72 dB(A) in JDB. These minimum sound pressure levels (LAmin) ranged from 44 to 46 dB(A) in BP and 50 to 57 dB(A) in JDB.

Table 1: Results of sound measurements at Bacacheri Park for 15 minutes

	Spots	LAmax	LAeq	LAmin	Description of locations
Bacacheri Park	1	74	56	46	Gym equipment at the park entrance
	2	76	54	46	Lane in front of the waterspout
	3	74	54	45	Gym equipment in the centre of the park
	4	78	58	44	Lane next to the soccer and volleyball courts
	5	75	57	45	Parallel lane close to Canada Street
	6	75	52	44	Parallel lane close to the barbecue grills
	7	69	52	45	Hiking trail parallel to the northern portion of the lake
Botanical Garden	1	81	64	54	Track along the shores of the smaller lake, parallel to Ostoja Roguski Street
	2	78	63	56	Track along the shores of the larger lake, parallel to Ostoja Roguski Street
	3	77	65	55	Gym equipment, parallel to Maurício Freut Avenue
	4	90	72	56	Lane parallel to Maurício Freut Avenue and at the forest perimeter
	5	84	72	62	Lane parallel to Prof. Lothario Avenue and at the forest perimeter
	6	74	54	50	Track behind the greenhouse and parallel to the contour of the forest
	7	79	58	53	Track in the centre of the park
	8	75	55	50	Lane, velodrome, the main entrance to the park
	9	78	63	57	Outdoor gyms

Source: SZEREMETA, 2012.

Subjective data were collected through interviews on samples of 82 persons in each park. Most respondents in Botanical Garden is made up of the male gender. In Bacacheri Park, the predominant gender was female. The dominant age group is from 18 to 29 years old (Table 2).

Table 2: Demographic data of respondent samples

	Botanical Garden		Bacacheri Park	
Gender	**Cumulative frequency**	**%**	**Cumulative frequency**	**%**
Male	42	51.2	40	48.8
Female	40	48.8	42	51.2
Age				
18 to 29	47	57.3	24	29.3
30 to 39	12	14.6	21	25.6
40 to 49	8	9.8	11	13.4
50 to 59	10	12.2	12	14.6
≥ 60	5	6.1	14	17.1

Source: SZEREMETA, 2012.

Regarding the sound sources (Table 3), human sounds were reported as perceived "all the time" in 40.2% of the responses from Bacacheri Park. And as "low frequency" in 39% of the responses from the Botanical Garden. Natural sounds were perceived "very" frequently in Bacacheri Park (32.9%) and the Botanical Garden (31.7%). The showed results indicate that such sounds could be perceived "at all times" (31.7%). Mechanical sounds were perceived as "very little" (32.9%) in Bacacheri Park and "very" (35.4%) in the Botanical Garden.

Table 3: Sound sources perception (categories)

	Human sounds		Natural sounds		Mechanical sounds	
Bacacheri Park	**CF**	**%**	**CF**	**%**	**CF**	**%**
1 = I didn’t hear anything	0	0	2	2.4	11	13.4
2 = Very little	5	6.1	4	4.9	27	32.9
3 = Little	21	25.6	23	28.0	26	31.7
4 = A lot	23	28.0	27	32.9	10	12.2
5 = All the time	33	40.2	26	31.7	8	9.8
Total	82	100	82	100	82	100
Botanical Garden	**CF**	**%**	**CF**	**%**	**CF**	**%**
1 = I didn't hear anything	3	3.7	2	2.4	0	0
2 = Very little	23	28.0	8	9.8	10	12.2
3 = Little	32	39.0	20	24.4	20	24.4
4 = A lot	13	15.9	26	31.7	29	35.4
5 = All the time	11	13.4	26	31.7	23	28.0
Total	82	100	82	100	82	100

Source: SZEREMETA, 2012.

As for the perception of sound quality (Table 4), Bacacheri Park was considered soundly "pleasant" (76.8%), "calm" (78%), "exciting" (61%) and "quiet" (73.2 %). The Botanical Garden was considered "pleasant" (59.8%), "calm" (56.1%), "exciting" (58.5%) and "quiet" (52.4%) for the most part.

Table 4: Sound quality perception

	Bacacheri Park		Botanical Garden			Bacacheri Park		Botanical Garden	
Pleasantness					**Agitability**				
	CF	**%**	**CF**	**%**		**CF**	**%**	**CF**	**%**
1 = ver pleasant	13	15.9	13	15.9	1 = very agitated	1	1.2	3	3.7
2 = pleasant	63	76.8	49	59.8	2 = agitated	14	17.1	31	37.8
3 = unpleasant	6	7.3	20	24.4	3 = calm	64	78.0	46	56.1
4 = very unpleasant	0	0	0	0	4 = very calm	3	3.7	2	2.4
Total	82	100	82	100	**Total**	82	100	82	100
Excitment					**Intensity**				
	CF	**%**	**CF**	**%**		**CF**	**%**	**CF**	**%**
1 = very exciting	1	1.2	2	2.4	1 = very quiet	0	0	1	1.2
2 = exciting	50	61.0	48	58.5	2 = quiet	60	73.2	43	52.4
3 = monotonous	31	37.8	32	39.0	3 = noisy	20	24.4	35	42.7
4 = very monotonous	0	0	0	0	4 = very noisy	2	2.4	3	3.7
Total	82	100	82	100	**Total**	82	100	82	100

Source: SZEREMETA, 2012.

The Botanical Garden has significant differences in sound intensity, agitation, and pleasantness concerning Bacacheri Park. The maximum, equivalent and minimum sound pressure levels had higher magnitudes in the Botanical Garden. Such magnitudes contributed to higher frequencies accumulated in negative responses regarding the sound perception descriptors reported above. Additionally, more mechanical sounds and fewer human sounds were noticed in the Botanical Garden compared to the Bacacheri Park.

4.2. Sound maps

The results of sound mapping of Bacacheri Park (upper quadrant images) and Botanical Garden (lower quadrant images) are shown in Figure 2, where the areas are displayed on the left in 2D and on the right in 3D. On the Bacacheri Park maps, sound levels are prevalent around 40 to 50 dB(A) (yellow). The warmer shades of orange to red, tending to blue, observed at the extreme edges of the maps, representing higher sound levels, originated from traffic flows nearby roads with a large circulation of vehicles. Already on Botanical Garden maps, the prevalence of warm reddish tones inside the park, indicating the sound propagation in the order of 60 to 65 dB(A). On the outer edges of the park, avenues and streets with a large circulation

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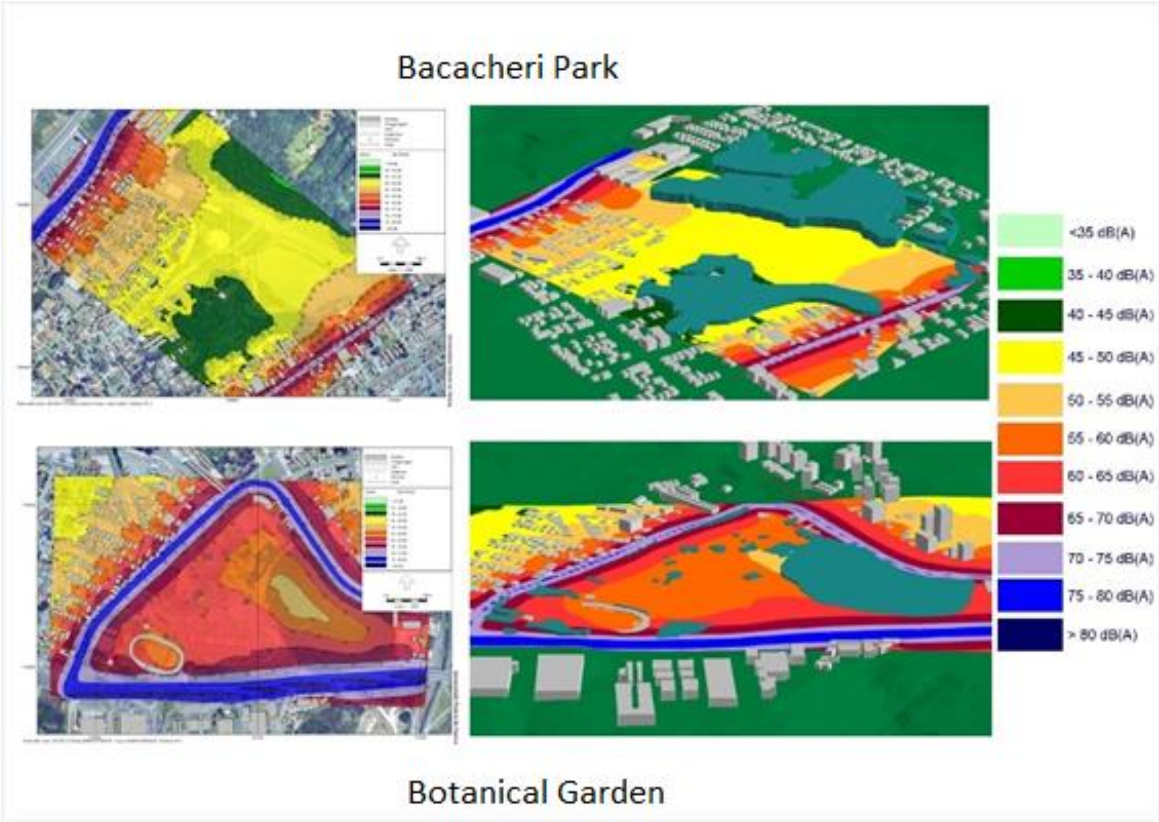
of vehicles can be observed, forming bluish tone corridors with sound levels in the order of 75 to 80 dB(A).

Figure 2: Sound maps – A-weighted sound pressure levels



Source: SZEREMETA, 2012.

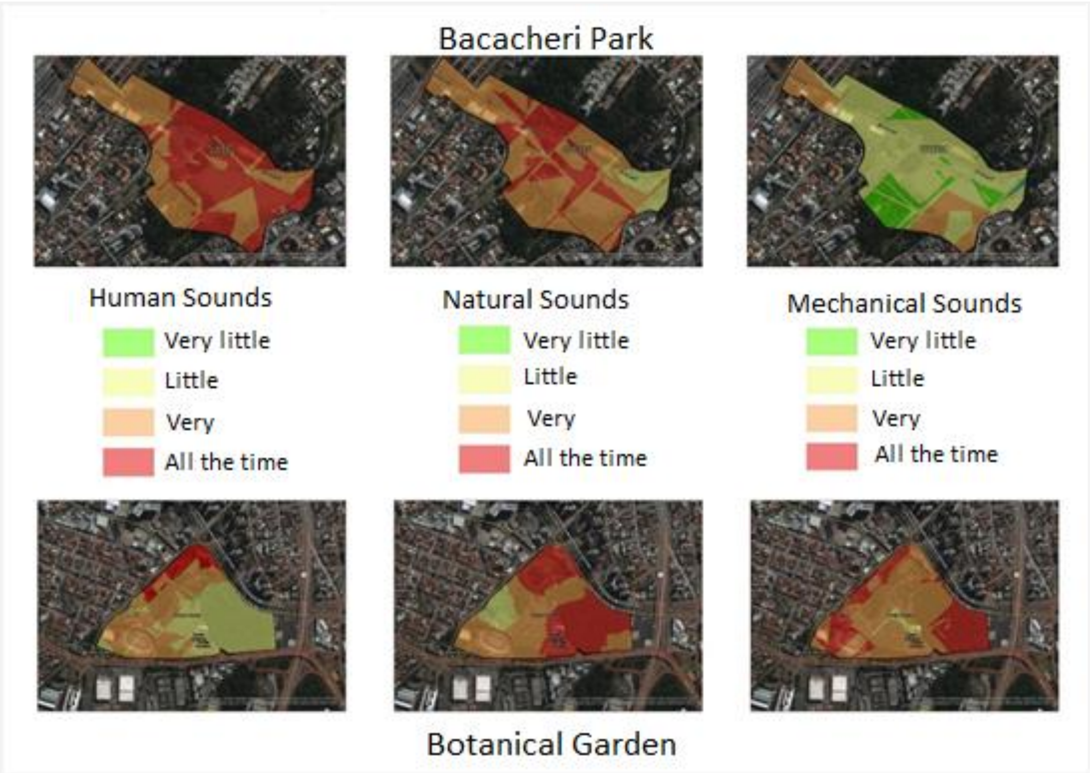
4.3. Sound perception maps

The mappings shown in the upper part of Figures 3 and 4 show maps of Bacacheri Park and the lower part of the Botanical Garden.

On the Bacacheri Park maps (Figure 3), there is a predominance of human sounds inside the park with red tones, where there is a lake and running tracks and stations for sports practice. The sounds of nature are constantly reported in the lake region. It is also reported near a forest in the upper middle area of the map. Mechanical sounds are very much observed at the ends of parks, close to the main access roads to the park, coinciding with the information from the sound mappings (Figure 2).

The perception maps of sound sources from the Botanical Garden (Figure 3) show the prevalence of human sounds in buildings where exhibitions occur, in the upper corner of the map in red. Sounds of nature are also observed in the same area due to the larger lake and the woodland region, lower right quadrant (red). Mechanical sounds prevail at the park's edges, also coinciding with the information from the sound mapping presented in Figure 2.

Figure 3: Perception maps of sound sources



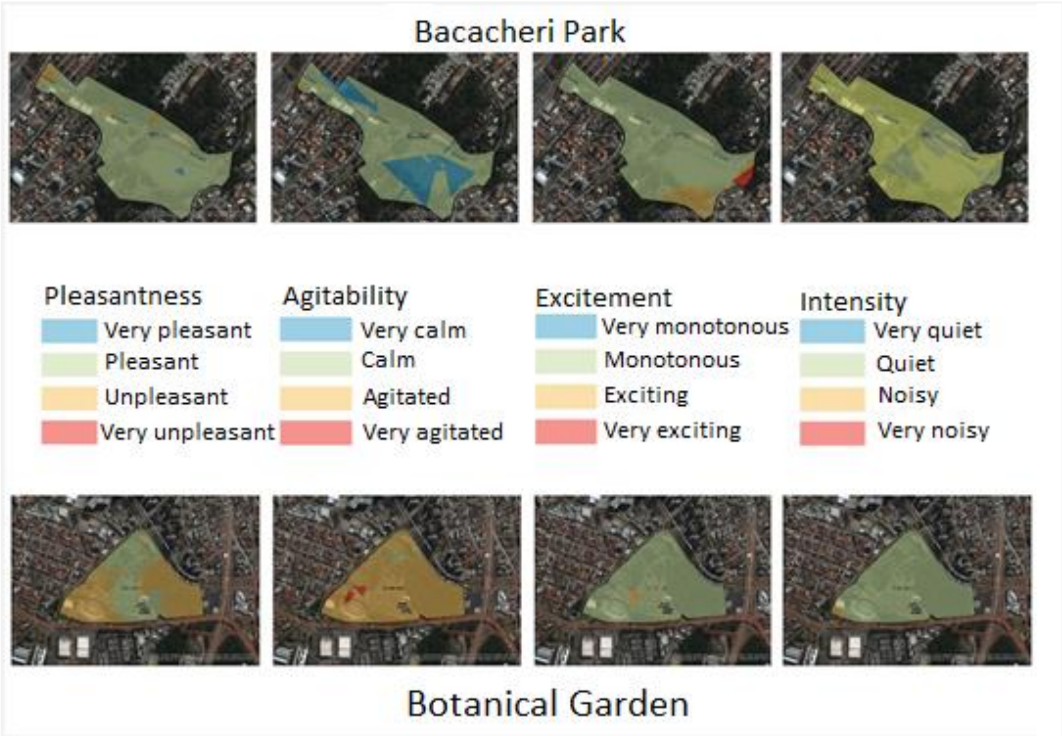
Source: the authors.

The sound quality perception mapping (Figure 4) indicates that Bacacheri Park is classified as sound pleasant in almost all areas, except the upper left corner (yellow), possibly due to traffic noise propagation from main neighbours roads. In general, sounds are classified as calm and in the lake and forest region as very calm (blue). Sounds are considered monotonous practically throughout the park. Still, there is a classification of exciting (yellow) and very exciting (red) in the vicinity of the park entrance on the lower right side. The park was also broadly classified as quiet and very quiet (blue) in the lake region.

Botanical Garden maps indicate the classification of unpleasant (yellow) on the lower left, where the velodrome is located, and on the lower right, where the forest is located, possibly due to the sound propagation of vehicular traffic from the neighbouring main roads. In the centre, the park was classified with pleasant sounds. In much of the park, sounds were classified as agitated (yellow). In the velodrome region, there is an indication of very agitated (red). There are islands on the upper side of the park, classified as calm (green) in the larger lake. Sounds were considered monotonous in much of the park, except near the velodrome (exciting – yellow). Much of the park was classified as quiet, except in the lower-left corner (noisy – yellow), possibly due to vehicular traffic in the region.

One of the motivations for the colour uniformity observed in sound quality maps is the sampling distribution of evaluation points. Perception data collection points were concentrated on the edges of parks. As the "Ordinary Kriging" is based on the distance between observed points, for the prediction of simulated points, the sound information of spaces inside the parks may be underestimated. For an adequate estimation, the adoption of the subjective data collection strategy at points stipulated by a "grid" is recommended, thus reducing the distances of data interpolation and enabling greater accuracy of the information, in addition to enriching details regarding the characteristics of sounds of the investigated areas (ENGEL; PFAFFENBACH; FELS, 2017).

Figure 4: Perception mapping of sound qualities



Source: the authors.

5. CONCLUSION

The present study aimed to characterise the soundscape of two parks in Curitiba, Bacacheri Park and the Botanical Garden. The triangulation method of methodologies proposed in ISO/TS 12913-2 (2018) was used to achieve this objective. The descriptive analyses of objective and subjective data and sound and perception mapping of the studied areas were performed.

It is noted that the integrated approach carried out with the triangulation of methodologies helped to first understand the differences between the investigated parks, with the quantification of sound and sound perception responses. The physical space, the most significant noises and the sound propagation of such noises were cartographically represented through sound mappings. Additionally, the verification of sound quality was carried out through sound perception mappings by identifying sound sources and sound qualities, mostly coinciding with the physical characteristics of the investigated spaces. Such facts corroborate for effective management of urban planning and environmental impacts to provide a better quality in urban comfort and environmental health.

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