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Beyond Park Boundaries: Exploring The Effect of Surrounding Land Use on Sound Levels of Parks

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Abstract

Urban parks in big cities can help reduce noise while providing spaces for recreation and rest, but their size, location and surroundings can limit their environmental benefits. This article will discuss how surrounding land use affects noise levels in a particular park, as well as how park landscaping can limit noise exposure. Four study areas were selected from Kuala Lumpur and Putrajaya to highlight a range of land uses, locations and park sizes. The sound levels were measured twice for each site-morning and evening-using measurement points along the park path and the SL-5868P sound level meter. The results showed that the study area exceeded the recommended noise limit of 55dBA as stipulated by Malaysian Noise Limit and World Health Organization guidelines. In addition, there was a pattern of influence on the measured noise levels based on land use and landscape around the park. Parks located in dense land use have higher noise levels, but have lower variation in noise levels within the park due to higher surrounding noise levels, compared to parks with more than 87% tree cover. The KLCC park, with 76% tree cover, has an overall higher noise level of more than 60dBA, indicating that the tree cover serves as a noise barrier for the park. Therefore, park planning should be tailored to its location and environment, while landscaping can be used to reduce noise levels and keep them within noise limits. In the future, the soundscape idea may be taken into account to enhance Malaysia's park environment.

1. Introduction

In the context of rapid urbanization and high-density developments, the increased noise levels contributed to an increasing sense of environmental unpleasantness. Developing nations including China, India and Vietnam experience increasing traffic noise pollution (Ma et al., 2006). This includes Malaysia where there is a constant increase in road transportation network to support the country's development process resulting in higher noise levels which degrades the quality of the environment. High density developments introduce elevated levels of human activities, higher vehicular traffic and industrial operations which increase noise pollution (Tong & Kang, 2020; Yuan et al., 2019). Meanwhile, the increase in urban population density amplifies the impact of noise pollution which negatively impacts the wellbeing of the residents. These concerns contributed to the recognition of urban noise pollution as a threat to environmental health.

To protect the urban community from this urban noise pollutions, the maximum permissible noise level at suburban and residential areas should not exceed 55 decibels (dBA) based on the environmental limit set by the Malaysian Department of Environment (Department of Environment, 2019). Similarly, the World Health

Organization (WHO) guidelines on noise level limit are fixed at 55dBA during the day and 45dBA at night. Research into these issues is necessary to secure the health and wellbeing of urban residents, as well as to ensure that planning decisions are based on evidence that considers the potential health and environmental consequences of development. Unwanted or disturbing sounds (noise) may not only be a harmful pollutant to human health as defined by WHO and European Centre for Environment and Health (European Environmental Agency, 2020) but they may also become a global and growing matter of concern that threatens the preservation of natural areas (Lynch et al., 2011). Consequently, public spaces are increasingly viewed as a potential setting for urban regeneration strategies.

The proximity of these developments to urban green areas results in heightened ambient noise levels within these green spaces which underscores the significance of mitigating noise infiltrations to parks to ensure the role of parks in enhancing the quality of life in the urban environment. Margaritis and Kang (2017) reviewed role of green areas to reduce noise levels in urban environment with geospatial analysis. Another study by Tashakor et al. (2023) developed a combined GIS-artificial neural network model to predict the spatio-temporal contribution of parks to mitigate noise pollutions in Iran, demonstrating a spatial relationship between land use, landscape, and noise level of parks.

Public spaces are a vital asset of a city. Urban parks are considered as one of the public spaces. The visual experience of a visitor is always considered to be the determining factor in why people visit the park . It is recognized that a good public space, especially urban parks with natural elements would benefit people's psychological and physical health and contributes to the increase of quality of life.

Understanding how urban parks attract more visitors has increased the significance of urban park soundscape knowledge in terms of providing comfortable acoustic experience in the park. Tse and Kwan (2013) highlighted the complex relationship among sound, environment, and individuals in investigating the soundscape quality of parks. A good acoustic environment is no longer simply the reduction of noise levels (Aletta et al., 2016; Hong et al., 2017) but the perception of the people of the acoustic environment as per the soundscape concept in ISO12913-1(International Standardization Organization, 2014). Soundscape perception of a park can be measured through a subjective aspect of non-acoustic factor by looking at people's perception of the landscape elements while the objective aspects relate to landscape characteristics, such as accessibility (Votsi et al., 2012), vegetation coverage (Dzhambov et al., 2018) landscape spatial pattern (Liu et al., 2014) and biodiversity (Gunnarsson et al., 2017).

Effect of Surrounding Land Use on Sound Levels

The surrounding land use of a park can affect its sound level. Land use categories are commonly used in national environmental noise polices to determine exposure limits implying the relationship between different land uses and sound level (Lechner et al., 2022; Department of Environment, 2019). According to Ajayi & Adeleke (2022), parks' surrounding with mixed-use land use including living and other activities records higher noise levels as compared to parks surrounded by purely residential areas. Margaritis et al. (2020) in their investigation of land use with sounds in urban environments, discovered a correlation between the urban form and distribution of activities and sound sources in the urban environment.

Wang and Kang (2011) found significant differences in the distribution of noise level between high- and low-density cities. Dense urban areas with numerous heavy structures tend to have higher noise levels (Sakieh et al., 2017). Findings of their study suggested there is a distance-dependent relationship between green areas and noise levels. Thus, landscape ecology plays an effective role in planning a greener and calmer city by exploring how noise propagation and built-up areas interrelate.

At a local scale, the surrounding land use of the park can affect the physical activity at the park and mediate the observed sound level within the park. A study investigated whether parks adjacent to neighborhoods with high land use diversity had higher levels of physical activity and interactions with the number of facilities in the park and found that parks with low surrounding land use diversity records higher physical activities in the park

(Huang et al., 2020; Kaczynski et al., 2010). However, parks located in commercial areas with busy streets may deter the public use of the park (Fry et al., 2021; Kaczynski et al., 2010).

Landscape as Noise Level Barriers

Noises in parks may be influenced also by the design of the park itself, such as placement of sound barriers and natural sound sources such as water features and vegetation (Di et al., 2021; Jaszczak et al., 2021; Sun et al., 2022). In terms of aural-visual interactions, numerous studies have suggested a close relationship between soundscape and landscape perception (Pheasant et al., 2010; Vijay et al., 2018). Votsi et al. (2012) mentioned a link between tranquility, environment quality and human health correlating with landscape structure. In addition, research has demonstrated that landscape features such as the normalized difference vegetation index (NDVI) and landscape shape index (LSI) can significantly influence the perception of certain sounds (Liu et al., 2013). NDVI is commonly used to estimate vegetation density and cover, the reflectance of vegetation and thus the NDVI values are influenced by a number of factors including canopy type, type of land use and seasonality (Liniger et al., 2016).

Densely vegetated areas are typically ecologically favorable habitats for organisms such as birds and insects and as a result they are often rich with biological sounds. When planned alongside a road, the dense vegetation of a park's landscape could also act as barriers, thereby affecting sound propagation and perception. According to a study by Liu et al. (2013), dense vegetation could reduce the perception of human sound, mechanical sound and geophysical sound. A study used spatio-statistical approach to model associations between noise pollution metrics of land categories including green covers and found that green covers were negatively associated with noise pollution levels (Sakieh et al., 2017). Similarly, natural features such as trees and shrubs, as well as man-made barriers can effectively hinder the propagation of noise (Uebel et al., 2022).

To date, few studies have examined how sound levels within an urban park vary according to its surrounding land uses and landscape. Studies on the influence of land use on sound levels have mainly focused on parks surrounded by residential land uses (Sun et al., 2022; Yuan et al., 2019). However, this study aims to focus on the impact of different types of land use such as commercial, institutional, and other public facilities on parks by prioritizing urban parks instead of neighborhood parks. This is because the location of urban parks in cities are crucial as a place of relaxation and the impact of sound levels on the restoration of the park users are more prominent in urban parks (Buxton et al., 2021; Fang et al., 2021). The aim of the study is to compare noise levels in the different parks and the characteristics of the landscapes. Therefore, this paper aims to extend the knowledge of the impact of the park's surroundings and the park's landscape on the sound level of the park. With this, the paper addresses the two (2) of question, (1) how the surrounding of the park influences the sound levels within the park and (2) does the landscape index of the park influence the sound levels in the park. This paper will examine the influence of a park's surroundings on the perception and experience of the park users.

This research will contribute to our comprehension of the environmental function of urban parks in dense cities by characterizing the urban park environment. The findings will also be important in identifying the implications for urban park planning and design, particularly with regard to how urban livability can be improved.

2. Data and Methods

2.1. Area Size and Locational Characteristics of the Parks

This study focused on the sound levels of the parks in Kuala Lumpur and Putrajaya (Figure 1), the nation's capital, and Malaysia's national federal administrative capital, to reflect an urban setting. A park's location by major roads may expose visitors to traffic pollution, and the size of the parks may influence the space for noise to attenuate (Lam et al., 2005). Three (3) types of parks were included in this study. The park type is determined by the GPP for the provision of public space in Malaysia (Department of Town and Country Planning, 2010) where the size of the parks corresponds to the number of inhabitants and functional recreational elements accorded to the site. City parks and district parks are recreational areas aimed to cater to the urban population

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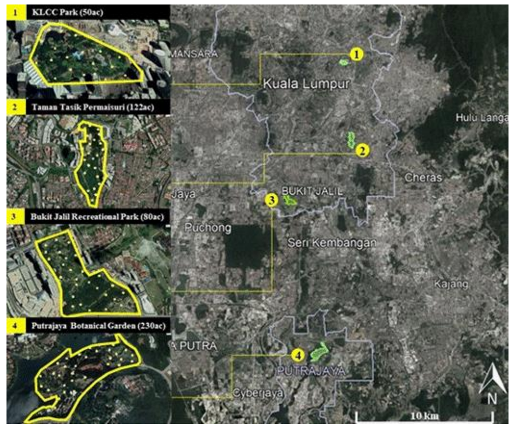
while metropolitan park offers opportunities for informal education facilities. The parks were selected based on their geographical attributes in terms of their surrounding land uses, location and size of the park which may have a profound implication on the park environmental quality. Table 1 details the geographical characteristics of the selected study area.



Source: Google Maps, 2019

Figure 1. Study Location of Selected Parks in Kuala Lumpur and Putrajaya

Table 1. Characteristic of the parks

No	Park	Type of Park	Description	Size (ac)
1	KLCC Park, Kuala Lumpur	City Park	Smaller hardscape and landscaped spaces for a highly intensified urban environment in the city center, provide breathing spaces for people to gather, socialize, rest and relax	50
2	Taman Tasik Permaisuri, Kuala Lumpur	District Park	Densely surrounded by several residential areas and is integrated with other sports and recreational facilities in the neighborhood	122
3	Bukit Jalil Recreational Park, Kuala Lumpur	District Park	Located on hilly terrain and surrounded by ongoing developments in the district, commercial buildings and residential areas and a golf resort. Also integrated with other sports and recreational facilities in the neighborhood	80
4	Putrajaya Botanical Garden, Putrajaya	Metropolitan Park	Located in the Putrajaya, often referred as "City in the Garden", the park is adjacent to the largest man-made pond and a neighboring park	230

2.2. Data Collection

2.2.1. Sound level measurements

This study employed measurements of sound levels in the parks based on objective acoustic environment by equivalent continuous sound pressure level (Shao et al., 2022). Like many other studies on acoustic environment in parks (Di et al., 2021; Evensen et al., 2016; Sudarsono et al., 2016; Sun et al., 2022), the acoustic measurements were measured based on the on-site soundwalk method where sound level measurements were taken along the park routes. Different observation sites were sampled due to the different sizes of these urban parks, with 20 points in KLCC Park, 27 points in Bukit Jalil Recreational Park, 24 points in Taman Tasik Permaisuri and 34 points in Putrajaya Botanical Garden, respectively (Figure 1). The SL-5868P sound level meter, held at a height of 1.5 meters above ground and at least 3.5 meters away from any sound-reflecting walls, buildings, or other structures, is used to measure the sound pressure level.

The SL-5868P was chosen in this study for its measuring features, which included the LAeq (equivalent continuous A-weighted sound level). LAeq is the standard weighting method for outdoor measurements represent the loudness of sound perceived by human ears for a real human reaction to the level of intensity and discomfort (Guo, 2019). The sound levels were measured in dBA values along the park routes. The distance between the measurement location and the ground was 1.2-1.5m (Mookiah & Ramasamy, 2018). It. One measurement was taken every 10 seconds. Each location's data was recorded for 5 minutes. Short duration samples can be justified in light of previous research and documentations (Axelsson et al., 2010; Oldoni et al., 2015). Spatial interpolation methods were then calculated using ArcGIS Pro with geostatistical methods (Kalisa et al., 2022), to fit a particular model to the data and allows the prediction of the sound levels at unsampled locations in the park.

2.2.2. Material and Software

The data for this study was collected from primary data sources which includes land use map and satellite imagery for the year 2021 and aerial photography to verify the current land use of the site surrounding (Table 2).

Table 2. Dataset Used in the Study

Dataset	Source	URL	License
Sentinel-2 Landsat 8 Satellite Imagery (2021)	EOS Land Viewer	https://eos.com/landviewer/	Public domain
Aerial Photography (2021)	Google Earth Pro	https://earth.google.com/web/	Public domain
Existing Land Use (2021) Kuala Lumpur & Putrajaya	ThinkCity	https://maps.thinkcity.com.my/think-city/maps/95345/downtown-kuala-lumpur	Open Data License
	iPlan- PlanMalaysia	https://iplan.planmalaysia.gov.my/public/geoportal?view=semasa	

Source: Analysis, 2023

2.3. Method of Analysis

2.3.1. Sound Level Data Analysis

Using Microsoft Office Excel 2016, the maximum noise level (Lmax) and the minimum noise level (Lmin) were calculated from the collected data. The park's equivalent noise level (LAeq) was calculated with Equation 1, in the unit dBA.

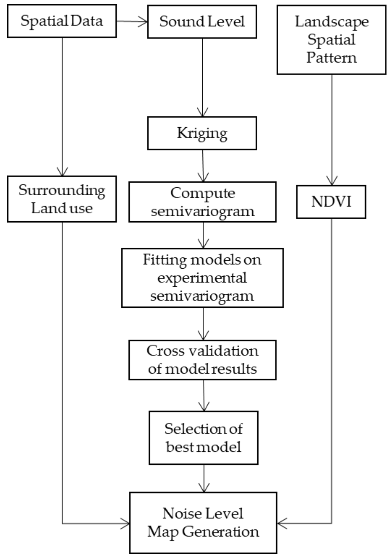
$$L_{Aeq} = 10 \log \sum_{i-t}^{i=n} (10)^{\frac{Li}{10}} (t_i) \ldots\ldots\ldots (Eq.1)$$

where n is the total number of samples taken, Li is the noise level in dBA of the ith sample, and ti is the fraction of the total sample time.

According to the Planning and Guideline for environmental Noise Limit and Control (Department of Environment, 2019), the noise level is considered to be in compliance if the LAeq value does not exceed the existing guideline for maximum LAeq by the receiving land use for planning and new development. Evaluations of L10 and L90 were performed in Microsoft Excel 2016 using [= PERCENTILE (array, k)], with k = 0.90 for L_10 evaluations and k=0.10 for L_90 evaluations. L_10 represents noise levels exceeding 10% of the measurements, while L_90 represents noise levels exceeding 90% of the measurements, known as background sounds in the area (Ismail et al., 2015; Napi et al., 2021). Analysis of Variance (ANOVA) test was then used to determine whether there was a statistically significant difference in the sound levels between each study area. Using ArcGIS Pro, sound maps were then created for the spatial analysis of the sound levels.

2.3.2. Spatial Analysis

Several spatial analyses were carried out to identify the characteristics of the selected parks and their relationship to the soundscape of the parks including park surrounding and park landscape mapping. Figure 2 details the steps undertaken for the study. All spatial analysis were computed using the ArcGIS Pro version 3.0.2 (E.S.R..I Inc. Canada).

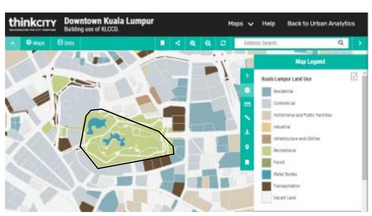


Source: Analysis, 2022

Figure 2. Flowchart of Research Analysis

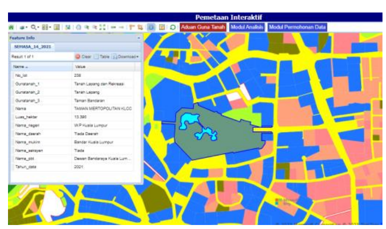
2.3.3. Spatial Mapping

Secondary data is commonly used in green space and recreation spatial analysis to look at the characteristics of neighborhood parks based on the aspect of the park location and accessibility (Malik et al., 2018). This study uses the secondary data obtained from the Interactive Web Map by Think City and iPlan Geoportal (Table 2) to extract the land uses of the plots surrounding the study area in Kuala Lumpur, the land-use masterplan for Putrajaya from Putrajaya Corporation's website and Google Earth Pro's satellite image dataset (Figure 3a).



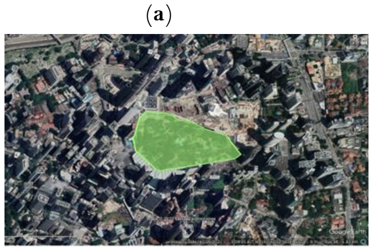
Source: ThinkCity, 2023

(**a**)



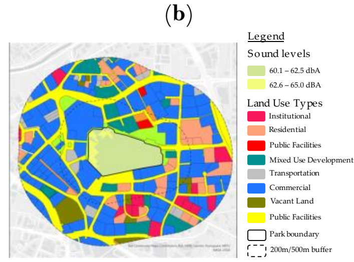
Source: iPlan geoportal, 2022

(**b**)



Source: Google Map, 2022

(c)



Source: Analysis, 2023

(d)

Figure 3. Spatial mapping method for surrounding land use (a) Land use map from Think City's interactive map; (b) Land use map from iPlan geoportal; (c) Satellite view of park surrounding from Google Earth Pro; (d) Land use of park's surroundings (post-verification?)

The satellite image utilized in the study is acquired during same period of data collection in November 2021 with the most accurate cloud-free imagery for the studied area (Figure 3b). The satellite image was mainly used to produce the urban form maps of the parks' surroundings to make sure that the data collected were accurate and precise for analysis (Figure 3c). A buffer of 200m and 500m from the park boundary was considered as the minimum impact of close proximity an infrastructure project such as roadway have onto developed areas in Guidelines of Noise (Department of Environment, 2019). The land uses of the park surroundings were validated with an on-site observation during the data collection process from November 2021 to August 2022 to update the land uses according to the current status of the building plots (Figure 3d).

2.3.4. Kriging Interpolation Analysis

Different spatial interpolation strategies can be used to produce sound maps (Aumond et al., 2018). Kriging interpolation has a solid statistical theory basis and can estimate an error point by point (Zuo et al., 2016), which is suitable for the present study. Although there are other interpolation methods that can be used to map sound levels, such as inverse distance weighting (IDW) and multiquadric interpolation (Harman et al., 2016), Kriging served as the best option in this study as there is at least moderate spatial autocorrelation among the sampled data points.

Kriging interpolation is used in this study to estimate the sound level of the park from the points of measurements taken within the study area. The dataset of sound level measurements in the park is used as the input dataset, semi variogram model and configuration of the type of Kriging to generate the best linear unbiased estimate at each location. Cross validation was used to assess the semi-variogram model, for the prediction accuracy of the interpolated sound levels in the park. The weights are determined from a spherical variogram based on the spatial structure of the data and applied to the sample points according to the formula in Equation 2, (ESRI, 2012):

$$Z(\chi_o - \mu) = \sum_{i=1}^{n} \lambda i \; Z(\chi_i) - \mu(\chi_o) \ldots\ldots\ldots (Eq.2)$$

where μ is a known stationary mean, assumed to be constant over the whole domain and calculated as the average of the data; the parameter λi is kriging weight, n is the number of sampled points for the estimation depending on the search window; and $\mu(\chi_o)$ is the mean of the samples within the search window.

2.3.5. NDVI Analysis

While there are several landscape spatial indices such as landscape shape index (LSI), Largest Patch index (LPI), and others commonly used to measure landscape fragmentations (Rutledge, 2003), NDVI (Equation 3) is commonly used to measure the effect of vegetation and prominence of sound sources, especially bio phony sounds of birds from the tree canopies (Leveau & Isla, 2021). It is also the most commonly used objective measure of vegetation density and is used to measure greenness exposure in urban settings for environmental health studies (Jimenez et al., 2022; Reid et al., 2018; Rhew et al., 2011).

The use of NDVI provides a quantitative measure of vegetation cover, which can be used to assess the impact of vegetation on sound levels in urban parks. Vegetation has been found to have significant effect on noise reduction, emphasizing on the impact of vegetation canopy and canopy density (Caprio, 2005; Guo et al., 2020). The dataset for vegetation greenness based on the area of interest (AOI) is extracted from a cloud-based GIS platform approach, which is built upon Dede & Widiawaty's (2020). research findings that the EOS platform can be used as an effective and efficient satellite image processing for vegetation greeneries. All vegetation greenness processing uses the EOS Platform accessed from Google Chrome (64 bit) browser.

The NDVI dataset in this study was collected from the Sentinel-2 satellite in the EOS Platform (cloud-based GIS vendor) using the Land Viewer, EOS Processing and EOS Storage. The analysis began by uploading AOI to the Land Viewer which then directs the map to the study area. Then, the sensor types and instruments, observation time, type of scene or mosaic data is entered into the platform. The NDVI workflow can then be selected for further analysis. Cloud coverage is limited to 0-10 during the acquisition of satellite images, data acquisition of satellite image is set to be within the study frame of November 2021 to May 2022. The satellite image with the least cloud coverage during the period of November 2021 to May 2022 is used for the NDVI analysis. NDVI values are calculated in relation with the following equation and for each pixel by using satellite images (Greenhill et al., 2003; Jiang et al., 2008; Jung et al., 2005).

$$NDVI = \frac{NIR[Band\ 8]-RED\ Band\ 4}{NIR[Band\ 8]+RED\ Band\ 4\}} \text{.........}(Eq.3)$$

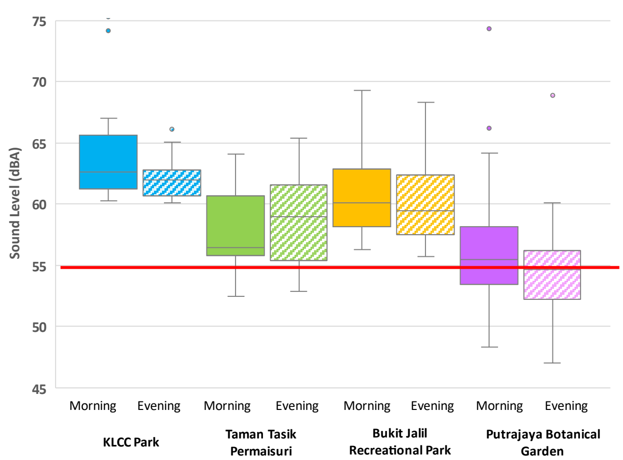
where NIR Band 8 and RED Band 4 represent the near-infrared and red band of Sentinel-2A image product, respectively.

3. Results and Discussion

3.1. Sound Levels of the Parks

The sound levels of the four parks obtained in this study is higher than the permissible sound level limit of 55dBA (Figure 4) for the parks designated by the DOE guideline and the WHO guidelines causing discomfort to some of the users, especially those who are more sensitive to noises (Department of Environment, 2019). This may cause interference with speech communication, disturbing individuals who want to converse or relax in the park. According to an ANOVA test, the sound levels were significantly different among the locations (F value=38.328, $p < .01$) suggesting that sound levels in parks could vary considerably between the different park types and locations.

The park with a significantly higher sound level was KLCC Park, with LAeq of 67.1dBA (morning) and 62.4dBA (evening) while the sound level in Putrajaya Botanical Garden is significantly lower than the other parks in the study with 61.6dBA (morning) and 57.4dBA (evening) (Figure 4). This suggests that the sound level of a park is dependent on the park's characteristics and the use of the park. Sound level for all parks slightly decreases in the evening because of the pattern of park usage with majority of the park users in Kuala Lumpur prefer going to the park for fresh air (Sreetheran, 2017). This is excluding Taman Tasik Permaisuri which demonstrated a higher sound level in the parks during the evenings (60.2dBA) as compared to the 58.7dBA during the mornings, suggesting that the park has a higher volume of activities early in the morning than in the evenings, which might be because it is situated in the midst of a residential area, thus promoting the use of parks for children's leisure in the evenings. This situation demonstrates how the decrease in the sound level of the park is linked to certain behaviors of the park users including their use of the park, and the influence on the park's surroundings on the sound level of the parks.



Source: Analysis, 2023

Figure 4. Sound Levels of the Selected Parks at Different Times of the Day

Noise levels were higher in KLCC Park and Bukit Jalil Recreational Park, surrounded by blocks of developments and heavy traffic (Figure 5a and 5d). Another reason of the high sound level in the park may be attributed to the large groups of people gathering by the park, evidently in KLCC Park where there is a large space for sitting by the musical fountain and in Bukit Jalil Recreational Park where there are areas designated for picnics and group activities in the park. The mean sound level of the Putrajaya Botanical Garden (57.4dBA during the evenings of a weekday) is the only park which is closer to the sound level limit for recreational areas. This can be justified by the surroundings of the park where Putrajaya Botanical Garden is located in Precinct 1 of Putrajaya with only administrative offices and a large man-made pond bordering of the park (Figure 5e and 5f).

KLCC Park presented a great difference in the sound levels of the parks during the mornings and evenings from 67.1dBA to 62.5dBA. This difference suggests that KLCC Park during the morning may be more influenced by the disturbance effect of noise events in its surroundings, such as the traffic noises in the city center. The background noises in the urban area contribute to the higher overall sound level of the KLCC Park (Figure 5a). Putrajaya Botanical Garden also recorded a difference approximately 4dBA during the morning (61.6dBA) and evening (57.4dBA), which can be attributed to variations in traffic volume related to land use, background institutional noise, and pedestrian activity. The park's large size may also reflect its variability where only certain areas of the park such as the area nearer to the park entrance have more activities while other sections of the park is quiet as the park is big and people may not travel through the entire park such as in Figure 5e which shows the lake broadways facing the calm lake.

Source: Photographs during Site Visit, 2022

Figure 5. (a) KLCC Park surrounded by high rise buildings; (b) Taman Tasik Permaisuri with an ongoing development of mixed-use building neighboring the park; (c) One of the main sources of biophonic sounds in Taman Tasik Permaisuri; (d) Bukit Jalil Recreational Park also overseeing high rise apartments; (e) Putrajaya Botanical Garden surrounded by a man-made lake and calm surrounding; (f) surroundings of Putrajaya Botanical Garden

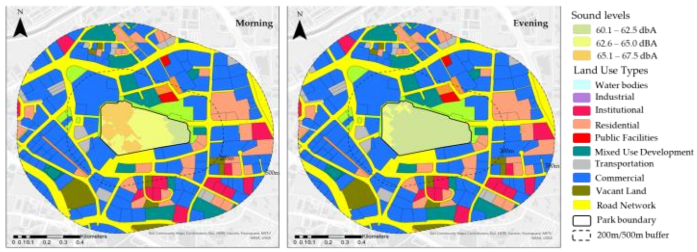
King et al. (2012) analysis the spatial and temporal variation in environmental noise with respect to land use. Their research concluded that there is a smaller noise variation in mixed use developments as compared to the noise levels in residential neighbourhoods. Similarly, findings of this research demonstrate the same effect where the noise level variation in KLCC Park, an area with mixed-use developments although has a higher mean sound level, but a lower variation as compared to the variation in sound levels of Putrajaya Botanical Garden with majority administrative land uses and Taman Tasik Permaisuri majorly surrounded by residential developments. However, findings of this study are not consistent with Napi et al. (2021) who investigated noise pollution in residential areas and commercial areas and found that although the noise level in Terengganu both exceeded the permitted limit, noise level in residential areas are higher than in commercial areas due to the traffic volume and noise from nearby activities. In this case, the sound level of the parks surrounded by mixed-use land use and commercial land use (KLCC Park and Bukit Jalil Recreational Park) recorded a higher sound level as compared to the ones surrounded by residential area (Taman Tasik Permaisuri). The sound levels in Taman Tasik Permaisuri during the time of measurement are mainly caused by the surrounding development of mixed development building, and the tree in the middle of the lake which attracts birds to the area (Figure 5b and 5c). The sound level of the park measured in the interior of the selected parks made it possible to study the pattern of the sound levels and its relationship to the surroundings of the parks. This can be justified by the landscape coverage of the parks and the involved sound sources which may decrease the sound pressure level with the progressive increase in distance from the noise source (Carvalho & Cleto, 2012).

3.2. Surrounding Land Use of the Parks

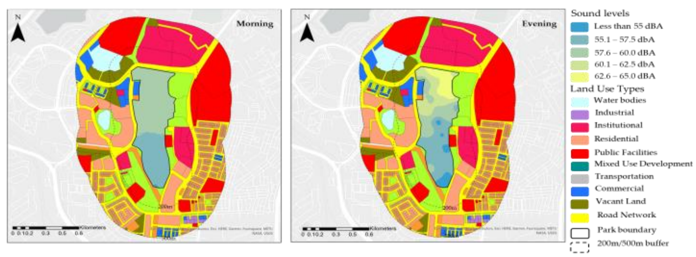
Figure 6a to Figure 6d illustrates the levels of sound measurement in the parks during peak hours of mornings and evenings. The results demonstrated a pattern in which higher sound levels were found at areas with high commercial land uses, for example in KLCC Park (Figure 6a) which is mainly sur-rounded by dense commercial high rises, and in Figure 6c where the west section of the park neighbouring a high-rise commercial building records a higher sound level in the park. Taman Tasik Permaisuri (Figure 6b) which is surrounded by higher density residential apartment to the west of the park also recorded a higher sound level, together with the northern section of the park which is bordering the highway. Putrajaya Botanical Garden in Figure 6d illustrates a low sound level (within the 55dBA noise level limit of parks) throughout most sections of the park due to its large size, fronting a large man-made lake along the park and institutional land uses surrounding the park which houses many government offices, resulting in a rather calm environment.

These findings suggest a pattern in which areas with high density commercial areas such as in KLCC central records a high volume of background sounds. As contrast, small commercial lots in a neighbourhood do not influence the surrounding sound levels of the park as much. This can be explained in terms of the activities large commercial areas have to offer and the higher pedestrian volume in the area. These results support the influence of human activities on the increase of noise level, which is in line with findings from Kalisa et al. (2022) who revealed a high risk of noise sensitivity level in city centres and areas with high volume of human activities such as the areas with a concentration of small businesses. Residential developments on the other hand, do not impact the sound levels of the park as much as commercial developments. Although there appears to be a pattern where high-rise residential developments do result in a higher sound level in the areas of park bordering such residential development. Reasons of the high volume could be attributed to the traffic flow of the area such as in Taman Tasik Permaisuri where the west side of the park is surrounded by apartments and the residents tend to park their vehicles by the roadside resulting in massive jams in the area. Another evident finding is that sound levels of all the parks appear to be higher at sections of bordering highways and busy roads as a result of the high background traffic sounds.

Commercial land use generates more noise pollution than open space with hard pavements or land used for residential purposes (Yuan et al., 2019) explaining the lower sound level in Taman Tasik Permaisuri surrounded by residential land uses and institutional areas (Figure 6b). On the other hand, Bukit Jalil Recreational Park is subjected to higher sound level due to the close proximity to the Bukit Jalil National Stadium and other commercial establishments. This can be explained by the volume of pedestrian activities and the commercial activities of the areas surrounding the park. Similarly, KLCC Park which is surrounded by the Petronas Twin Towers, Suria KLCC shopping mall and various office buildings, is likely to experience higher sound levels due to the commercial activities in the area. Similar to the area fronting the lake in KLCC Park (Figure 6a), commercial areas have higher noise level because of the number of people lingering in the area and the use of loudspeakers to attract clients to shop and music playing. That is why commercial land uses, which often include many streets for pedestrians and large retail areas, frequently result in a high-noise environment due to crowds of people and loud entertainments (Meng & Kang, 2015; Oyedepo & Saadu, 2009).



(**a**)



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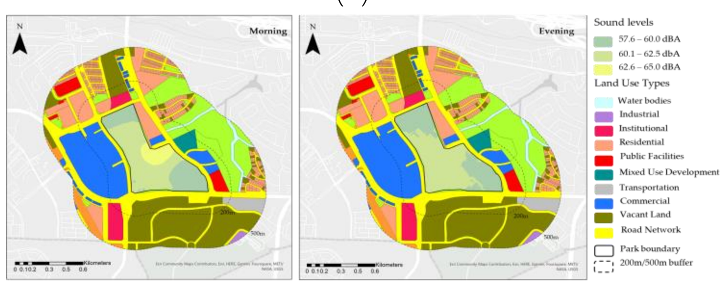

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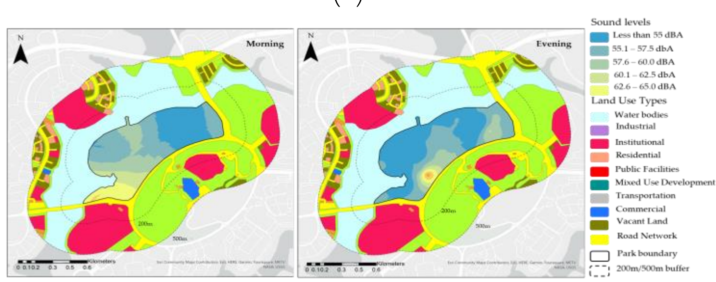


Source: Analysis, 2023

(**d**)

Figure 6. Sound levels extracted from the interpolations of the measurements in the park (a) KLCC Park; (b) Taman Tasik Permaisuri; (c) Bukit Jalil Recreational Park; (d) Putrajaya Botanical Garden.

Comparing Putrajaya Botanical Garden and the other three parks in the study, Putrajaya Botanical Garden has the lowest sound level due to its surroundings where the only type of buildings within 200m of the park boundary is Institutional and Public Facilities which are located further from the park's border. Although the park is surrounded by some commercial land uses, it is comparatively isolated from major commercial activities, which may result in a lower sound level of the park. These types of land uses do not produce many noises; thus, the sound level of the park is not affected by its surroundings and is only slightly over the permitted noise level by the Department of Environment and the WHO noise limit of 55dB. The only type of sound source which would significantly influence the sounds heard within the park is the traffic noise from the surrounding highway into the park. The lower sound level in Putrajaya Botanical Garden can also be explained by the presence of trees functioning as acoustic barriers and/or by the sound attenuation due to the increase of the distance from traffic road. Results of the research is supported by King et al. (2012) who highlighted that business zones document elevated levels of noise pollution, and noise levels in mixed land use areas are greater than in single land use areas.

Relationship between Park's Surrounding and Sounds Levels within the Park

The primary reason that land use types significantly affect sound levels in urban environment is associated with the varying levels of human activity, traffic and noise-generating sources. This study's spatial analysis of the park's surrounding and the park's sound level revealed that parks are louder when surrounded by residential developments and in central business districts, but quieter in areas with a high proportion of green space and institutional land uses. The high sound level of KLCC park, which is located in the city centre is reflective of its location in the central business district. This is in line with findings from Baloye and Palamuleni (2015) who compared the noise pollution levels in urban centres of Nigeria and discovered that noise disturbance is significant in areas with high population density, and has a negative impact on people's daily life, sleep, work and study. It also agrees with the findings by Margaritis and Kang (2017) revealing strong correlations were identified between 60% to 79% that lower noise levels were detected in the cluster with higher green space coverage.

The sounds generated within the park are reflective of its surroundings, and the allocation of activities within and surrounding the park. Commercial areas have higher sound levels due to the high human activity, traffic and presence of businesses that generate noise such as restaurants, shops, and entertainment venues. This is similar to KLCC park neighbouring Suria KLCC Twin Tower, which is fronting the restaurants and entertainment shops of KLCC, attracting a large number of visitors to the area at all hours of the day. Noise levels associated with urban land use have been found to be higher in commercial sites (70.0dBA) as compared to other land use types (Kalisa et al., 2022). In contrast, residential areas have lower sound levels because they consist of residences and living spaces, with the noise levels influenced by the population density of the residential area and the commercial or industrial activities (King et al., 2012). Mixed use areas, where commercial and residential land uses coexist, may experience elevated noise levels because of the combination of various noise sources and human activities (Lechner & Kirisits, 2022).

Areas of the park near major construction sites and major roads have higher sound level measurements. Traffic conditions such as congestion and vehicle types also influence the noise level experienced within the park, which can be observed during the peak hours of traffic in Bukit Jalil Recreational Park and Putrajaya Botanical Garden. This shows that the size of the roadway and traffic conditions in the vicinity of the park can have an impact on the sound levels within the park. It is consistent with findings from Papafotiou et al., (2010) and Papafotiou et al., (2004) indicating that larger roadways with higher traffic volumes produce more noise which penetrates the interior of the park.

Land uses associated with transportation and commercial activities in developing country cities contribute to the increase in noise pollution, as high noise levels in cities are attributable to traffic congestions resulting in honking and noise generated during the movement of vehicles (Aditya & Chowdary, 2020; Vijay et al., 2018). Thus, it is implied here that land use type such as transportation and commercial land uses affects noise pollution and the sound levels of the nearby parks. Margaritis et al. (2020) also found that areas of recreational and residential area showed dominance of natural sounds and human sounds; as compared to areas with mixed-use land uses such as commercial, industrial, institutional and residential with traffic sounds dominating the soundscape; and areas with commercial and recreational only having dominant human sounds and is less likely to be affected by traffic sounds. However, natural sounds were found to be almost imperceptible in these areas. Denser urban environments also typically have a higher noise level due to the increased traffic and human activity (Wickramathilaka et al., 2022). Tall commercial buildings are often found in central business districts, such as in KLCC Park. Building height reflects and scatters sound waves, which either increase or decrease the noise experienced within the park depending on the specific urban configuration (Yildirim & Arefi, 2023). In other words, taller buildings create noise barriers that prevent noise from entering the park, whereas shorter buildings may allow more noise to penetrate the interior of the park.

Factors such as building heights, distance from park, density of the area, size of roadway and traffic conditions all play a role in determining the noise levels experienced within the park (Counts & Newman, 2019). The sound levels of the parks in Malaysia exceeded the permissible limit for both day-time and night-time, indicating that the parks in Malaysia are exposed to high noise levels from surrounding land uses, and that the acoustic environment in the parks may not be quiet enough for a good restoration. Similarly in an urban park in Madrid, park visitors closer to a major road reported lower levels of perceived restrictiveness and tranquillity compared to those further away (Matsinos et al., 2008). Therefore, noise pollution from traffic or other sources can disrupt the tranquillity and sense of escape that people seek in natural environments

3.3. Effect of Landscape Spatial Pattern on Sound Levels

Spatial patterns of local landscapes could affect soundscape perception through landscape composition and landscape configuration (Benocci et al., 2022; Liu et al., 2013). The sound levels experienced within the park can have an impact on its calm soundscape. The landscapes of the parks, especially at the border of the parks, allow for the reduction of the sound levels, as a noise barrier. The landscape composition of the park was analysed through the NDVI values of the park's spatial landscape characteristics, as illustrated in Figure 7 and further break down in Table 3. According to the U.S. Geological Survey (2018), NDVI values ranges from 0.1 – 0.2 are barren rocks and open soils, while NDVI of 0.2 – 0.5 are sparse and moderate vegetations such as grasslands and shrubs. Higher NDVI values of 0.4 – 0.9 include dense vegetation such as trees canopy.

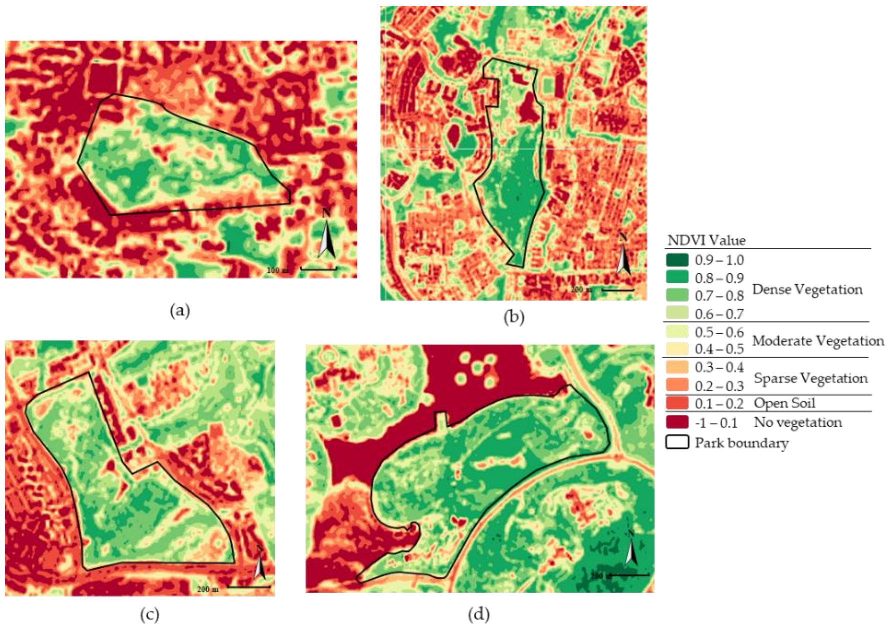
Table 3. NDVI Values of the Selected Parks

	KLCC Park	**Bukit Jalil Recreational Park**	**Taman Tasik Permaisuri**	**Putrajaya Botanical Garden**
Size (ha)	20.23	32.37	49.37	93.08
Land cover (ha (%))				
Tree canopy	15.80 (78.1)	29.17 (90.1)	43.05 (87.2)	88.15 (94.7)
Shrubs	0.99 (4.90)	1.92 (5.92)	2.29 (4.64)	3.26 (3.5)
Land	1.56 (7.73)	0.87 (2.69)	1.12 (2.27)	1.05 (1.13)
Water & Artificial surfaces	1.88 (9.28)	0.42 (1.29)	2.89 (5.86)	0.59 (0.63)
Total percentage (ha (%))	20.23 (100.0)	32.97 (100.0)	49.37 (100.0)	93.08 (100.0)

Source: EOSDA LandViewer, 2022

NDVI value is higher in Putrajaya Botanical Garden with its surroundings surrounded by areas with vegetations and water surfaces (Figure 6d). There is a clear pattern in which darker greens were observed at the borders of the park to reduce the noise levels from the close proximity to the highway into Putrajaya. This is in agreement that the existence of walls in the perimeter of the urban parks' functions, even partially, as noise barriers (Carvalho & Cleto, 2012). The big area of water surfaces (Red) at the border of the park, which is the man-made pond in Putrajaya, also contributes to the lower sound levels measured within the park. The center of Putrajaya Botanical Garden recorded high percentage of tree canopies with dense vegetations (Figure 7d), suggesting that the presence of bio phony sounds such as animals and birds in the area would be higher than in other sections of the park explaining the higher sound level in the area (Figure 6d). This is also in line with findings from Leveau & Isla (2021), that areas with NDVI index of higher than 0.3 has a higher presence of bird sounds, which increases the diversity of bio phony sounds in the area.

Taman Tasik Permaisuri showed similar high NDVI tree coverage in the southern sections of the park, where people described it as a 'forest-like' area (Figure 5b). Interestingly, the sound levels in this section of the park are lower than other parts of the park (Figure 6b), which is different from the comparison of sound level and NDVI in Putrajaya Botanical Garden (Figure 6d). This may be because while Putrajaya Botanical Garden is relatively quiet due to the low volume of visitors and the large size of the park, the sound levels observed in the park is mainly contributed by the sounds of nature in the park; while Taman Tasik Permaisuri which is located in a residential area, have a higher volume of people using the park, resulting in a higher sound level at the northern area of the park where people gather for social activities. Figure 6b and 6d also demonstrated the lower sound levels of the two parks, justified by the higher tree coverages in the two parks acting as a noise barrier to the surrounding noises from outside the park. This may be a part of the reason Putrajaya Botanical Garden and Taman Permaisuri are described similarly to the park visitors as an area for relaxation and recreational purposes.



Source: Analysis, 2023

Figure 7. NDVI Values of the Parks (a) KLCC Park; (b) Taman Tasik Permaisuri; (c) Bukit Jalil Recreational Park; (d) Putrajaya Botanical Garden

It is also clear from the NDVI figures of KLCC that the park's surroundings are high with artificial surfaces, indicating a limited area of green spaces within close vicinity to the park (Figure 7a). It is almost similar to the Bukit Jalil Recreational Park where the surroundings of the park are commercial and residential development, except for the section towards the north of the park surrounding, where it is a golf and country resort. From Figure 6a, KLCC Park showed a higher overall sound level and a smaller noise level variation as compared to Taman Tasik Permaisuri and Putrajaya Botanical Garden. This can be explained by the location of the park highlighted in the previous section, as well as the lesser tree coverage in both parks. In other words, the location of KLCC Park in the central business district, as well as the lower vegetation density in the park, increases the background sounds within the park, explaining the higher sound levels heard from within the park. In this case, noise events such as noises from children playing or conversations would be less noticeable in KLCC Park as compared to other parks.

The percentage of tree coverage in KLCC Park is the lowest at 78.1% compared to the other parks which are well over 87.0%. This may contribute to the higher mean sound level of the park and higher percentages of sounds from human activities (anthrophonic activities) as there are lesser biophonic sounds in the park. The findings here agree with Dzhambov et al., (2018) that green space with higher NDVI percentage which signifies greater tree cover are mediated by the lower sound level of the parks and reflects lower noise annoyance. According to Benocci et al. (2022) different urban environments and natural sound abundance contribute to the different soundscape scenario. The heavier tree coverages are located by the border of the park as a barrier to the noises outside the parks and increases the biophonic sounds heard from within the park.

Impact of Park Landscapes on The Sound Levels

NDVI index has been used to monitor changes in land use patterns surrounding urban areas (Ehsan & Kazem, 2013) and the abundance of vegetations around people's home (Larkin & Hystad, 2019). Evidently in Figure 7a which reflects a park located in a dense urban environment, the NDVI of the park's surroundings are reds (<0.2), suggesting very limited vegetation coverage in the surroundings while showing greens (>0.6) within the boundaries of the park. Places with low NDVI value showed low level vegetations scattered around in small bits (Teeuwen et al., 2024). This suggests that the park environment of KLCC Park offers great contrast from its dense urban surroundings. Likewise, in Singapore, the NDVI of urban areas ranges from 0.4 – 0.6, indicating a high vegetation coverage across the city (Gaw et al., 2021). Therefore, in comparison, the role of parks in Malaysia are more evident as a space for getaway of the urban environment and demonstrates a higher significance on the reductions of urban sound levels in the parks.

The result showed that sound levels are higher across all four parks at areas with lower NDVI values, indicating less tree coverage in the area. This agrees with the analysis of de Oliveira et al. (2022) that planting varied vegetation typologies such as trees and shrubs in high density efficiently contributes to noise reduction. This is also similar to the finding that areas of parks with trees surrounded can be perceived as the 'quietest' while paths along areas of grass can be perceived as the 'loudest' (Guo, 2019). It suggests that vegetation coverage may contribute to a part of the observed result of sound levels within the park, because of the biophonic activity driver. Certain sound categories may also be influenced by the varieties of land cover and their spatial characteristics. Liu and Shen (2014) mentioned in his study of city parks that human sound perception showed close relationship towards water and building land cover. Their research also highlighted the correlation between soundscape diversity and that water areas were perceived as positive, suggesting that adding water features to parks could increase their appeal to parkgoers.

The use of vegetation in urban planning and park design to reduce noise pollution is becoming increasingly common. The increase of vegetation cover in the form of forest and grassland is recommended to help reduce urban noise (Akay & Önder, 2022; Han et al., 2018; Ow & Ghosh, 2017) where green buffering zones can be installed to minimize the impact of noise on surrounding land uses (Yuan et al., 2019). Forest, trees and shrubs are effective for managing noise pollution, other types of land cover can also be useful considering the seasonal variation in attenuation across diverse land covers of urban environment. Thick-branched and densely covered trees and bushes can act as natural sound barriers and lowers noise levels (Papafotiou et al., 2010). Jaszczak et al. (2021) agreed that park design elements such as the arrangement of vegetation can also influence the park's ability to reduce noise levels. Another study by Akay and Onder (2022) suggests that plant groups and the distance between the noise source can help with traffic sound mitigation.

While anthropogenic noise is increasing globally due to population growth, increased transportation and resource extraction, land cover can influence noise attenuation (Gaudon et al., 2022). In a study conducted in Shenyang, China (Yang et al., 2019), the impact of high-density urban traffic noise on acoustic environment of urban parks were analyzed, revealing that parks were clustered, and LAeq of the traffic sound simulation on the roadways adjacent to the parks ranged from 59.0-70.9dBA, with a specific pattern based on time and day.

Both Tasik Permaisuri and Bukit Jalil Recreational Park have a high wall surrounding the park and multiple natural features to hinder the transmission of noise inside the park. The areas where such landscape exist in Bukit Jalil Recreational Park, neighbouring the busy highway adjacent to the park, showed that traffic sounds were lower due to sound absorption effect. This is similar in Lu Xun Park where areas affected with traffic sounds were designed with multiple natural landscapes for sound absorption (Yang et al., 2019). The study also revealed that as one moves deeper into the interior of the park, the sound levels and perception of traffic noises decreases. This is influenced by the spatial characteristics, landscape characteristics and sound composition in the parks. Sounds were more likely to be reflected with paved grounds, making it not conducive to the attenuation of traffic noises.

Landscape planning of a park is also carried out as a method of redesigning places most exposed to noise to maximise the soundscape perception in three parks in Olstyn, Poland (Jaszczak et al., 2021). The study then proposes two design activities to address noise reduction through the reduction of undesirable sounds and the introduction of desirable sounds to the park. Similar to the parks in Malaysia, areas which are most exposed to noises are often located at the park boundaries along the main access roads and park entrances. Therefore, similar measures of sound intervention can be considered in the planning phase of urban parks to minimize the impact of surrounding sounds and increase the beneficial influence of natural sounds for restoration.

3.4. Implications from the Effect of Land Use and Landscape on Sound Levels of Parks

This research focuses primarily on the influence between landscape and sound level, hence NDVI is used to examine the effect of vegetation density on sound level. In such context, it can be applied during the planning stage, to determine the suitable location for urban parks, as well as to propose plants with dense tree coverage especially in borders of parks at dense urban areas to minimize the impact of surrounding noises on the acoustic environment of the parks. This is essential to ensure and maximize the park's function as a space of leisure, social activities, and relaxation. Similar to a study in Hong Kong (Lam et al., 2005), which emphasized the need of urban parks as a place of social functions rather than environmental functions, urban parks in Malaysia should be designed to provide greenery and social space for the urban community to relax and interact with one another to provide greenery and the social space for urban inhabitants to interact with one another.

Research findings in this study demonstrated the pattern of land-uses and the landscape (vegetation coverage) in influencing the sound levels of the parks in Malaysia. This is crucial so that in the future planning of a park, the surrounding land uses, and its existing sound levels should be taken into consideration to minimize the impact of noise on the park's environment. In the context of an existing urban environment, land use that is proposed to be in an area with a generally intolerable noise level may be permitted if the impacts and benefits of the proposed land use in that location are weighed. According to Mennitt et al. (2014), maps can be generated to represent and predict the consequences of sound level variation on landscape in different scenarios. In such cases, mitigation actions involving the use of landscape as a strong noise barrier should be considered.

This is reflective in the City of San Diego General Plan (City of San Diego, 2008) which states that parks should be in calm locations whenever feasible and that noise exposure levels should be considered during the planning and design process. Place the most noise-sensitive uses, such as children's playgrounds and picnic tables, in the site's calmer areas when the parks are in livelier areas. These mitigation actions help to enhance the park's environment for a better restoration and relaxation purpose as well as increasing the health benefits of the urban parks. As Margaritis and Kang (2017) highlighted, noise pollution is significantly influenced by urban design, urban density, urban morphology, street distribution, street environment, and urban land use. Gerolymatou et al. (2019) also noted that the design of public spaces and activities hosted within the neighbourhood buildings can have a significant acoustic impact on the sound comfort experienced by the residents.

The noisiest park among the four-study areas is KLCC Park, the smallest park in the study located in the most central area of Kuala Lumpur city. The sound level within the park records decibels above 60dB(A), dominated by sounds from the surrounding land uses of high-density commercial areas and road traffic. The least noisy park in the study area reflects the biggest park among the study area located in Putrajaya. Also reflective of its location, the park's surrounding is rather peaceful with a large portion of the park bordering the man-made lake of Putrajaya while the other sections border the highway into Putrajaya. Tranquility perceived in different environments is based on the visual and acoustic characteristics. However, the dense tree coverage as seen from the NDVI analysis illustrates the significant function of the shady trees as noise barriers to the park. The role of landscape coverage in influencing the sound levels of the parks is evident in Taman Tasik Permaisuri's lower sound levels at the southern sections of the park, which is high in its NDVI level, signifying a dense tree coverage.

The findings of this study suggest that there is a pattern in the influence of parks' surrounding land use and landscape of the parks on the sound levels measured in the park. These results confirm that especially in urban environments with high densities and busy settings, the sound levels measured within the parks located in such environment to be higher that the permissible noise level limit of outdoor spaces (55dBA), which may cause possible interference in speech intelligibility and some inconvenience to visitors who wish to communicate or relax in these spaces. These analyses suggest that the ability of urban parks to improve the sound quality is limited.

4. Conclusion

The study contributes to the understanding of the role of parks from the influence of the surrounding sound level and the importance of vegetation coverage in parks to mitigate the urban sounds, especially in urban areas. This study demonstrates how surrounding land use provides opportunities for vibrant activities and pedestrian flow will increase the sound levels of the park. It also shows how landscape of the park in terms of the vegetation density can be used to reduce the impact of surrounding sounds for a calmer park experience.

Even though NDVI indices can be used as an indicator of the how vegetation coverage reduces surrounding sounds into the park, it would be beneficial if the perception of the park visitors were taken into consideration as well to provide a deeper insight of how perceived sound sources and volume have an impact on visitors' experience. For example, further studies can be carried out to measure how and why dense vegetation coverage leads to higher biophonic activities and the effect of biophonic sounds on park experiences. Therefore, a limitation to this study is that the influence of landscape and land-use of the parks' surroundings in this study were only measured by the objective measurements of the sound levels.

While the perceived sound level of the park visitors may differ according to their tolerance of noise levels, it is likely that the influence of sound level on the visitors' perception may differ according to the personal preferences of the park visitors. Hence further study should investigate the relationship between people's perception of the sound levels of the parks. The study also uses NDVI to measure the landscape spatial pattern on sound level. However, NDVI only measures the amount of vegetation in an area and does not provide information on the type or quality of the vegetation. Although NDVI index on its own can be used to measure the relationship of vegetation density with sound level, it is not sufficient to differentiate between the sound component of the parks due to the acoustic complexity of the area and to identify the effect on the soundscape perception of the park visitors. This suggests that other types of landscape indices can be considered in investigating the relationship between landscape spatial pattern and sound levels for a thorough understanding of landscape effect on acoustic perceptions. This study is also limited to the sound levels measured from within the park boundaries thus will benefit from the comparison of the sound level at the exterior boundary of the park and the internal boundary of the park. Future studies would benefit to include that aspect as to validate and examine the relationship between the influence of tree canopies as effective noise barriers from the surrounding noises.

As parks play a role in promoting recreation, park planning and design should consider including soundscape interventions, NDVI and land use analysis to see which areas may be prone to noise pollution so that actions on mitigation can be planned. The purpose of a park is for recreation and relaxation from busy urban settings; therefore, its environment should always be conducive for recreation purposes. Conflicts of park use due to its inconducive environment should always be minimized to the very least to maximize the benefits of parks in cities. Therefore, further emphasis should be undertaken on the concept of soundscape in parks to enhance the park environment in Malaysia.

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