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GIS Based Urban Noise Pollution Analysis and Mapping: The Case of Antalya, Turkey

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ABSTRACT

In this study, it is aimed to determine the urban noise level, to classify it according to the provisions of the relevant regulation, to map it using geographic information systems (GIS) and to develop physical and administrative suggestions for eliminating the noise above the threshold value. In this context, the city center of Antalya was chosen as the study area. This area was digitized, and its maps were produced with the help of remote sensing and geographic information systems. Then, the noise levels of the region were measured using a decibel meter, provided that it was evenly distributed throughout the study area, all measurement points were coordinated, transferred to the map and a database was created. Interpolation was applied based on the noise threshold values in the "Evaluation and Management of Environmental Noise" regulation in the national legislation, noise levels were classified and noise maps were produced. In accordance with the relevant regulation, land survey was carried out again for the regions exceeding the noise limit values, and the sources of noise were identified. In line with the results, physical and administrative solutions have been developed for the elimination of noise in the region.

Keywords: GIS, Geographical information systems, noise mapping, noise pollution, urban problems

CBS Tabanlı Kentsel Gürültü Kirliliği Analizi ve Haritalandırılması: Antalya Örneği

ÖZ

Bu çalışmada kentsel gürültü düzeyinin belirlenmesi, ilgili yönetmelik hükümlerine göre sınıflandırılması, haritalanması ve eşik değerin üzerindeki gürültünün giderilmesi için coğrafi bilgi sistemi (CBS) teknolojileri kullanılarak fiziki ve idari öneriler geliştirilmesi amaçlanmaktadır. Bu kapsamda çalışma alanı olarak Antalya şehir merkezi seçilmiştir. Bölge, uzaktan algılama ve coğrafi bilgi sistemleri kullanılarak sayısallaştırılmış ve haritaları üretilmiştir. Ardından çalışma alanı bütününde eşit olarak dağılım göstermesi koşulu ile ölçüm noktaları belirlenmiş, bu noktalardan desibelmetre ile gürültü seviyeleri ölçülmüş, haritaya aktarılmış ve veri tabanı oluşturulmuştur. Ulusal mevzuatta yer alan “Çevresel Gürültünün Değerlendirilmesi ve Yönetimi” yönetmeliğinde yer alan gürültü eşik değerleri baz alınarak enterpolasyon uygulanmış, gürültü seviyeleri sınıflandırılmış ve gürültü haritaları üretilmiştir. İlgili yönetmelik gereği gürültü sınır değerlerini aşan bölgeler için tekrar arazi etüdü yapılarak gürültü kaynakları tespit edilmiştir. Elde edilen sonuçlar doğrultusunda bölgede gürültünün giderilmesine yönelik fiziki ve idari çözümler geliştirilmiştir.

Anahtar Kelimeler: CBS, coğrafi bilgi sistemleri, gürültü haritalama, gürültü kirliliği, kentsel problemler

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INTRODUCTION

Noise pollution is one of the most common environmental problems in today's world and is the subject of scientific research (Bostanci, 2018) because of its physical and psychological effects on people. In this context, mapping and analysing noise pollution, especially in urban areas with high levels of population density, plays an important role in directing management and governance plans.

Noise that can be defined as unwanted sound (Morillas et al., 2018), has become an important problem that can cause temporary or permanent damage to humans and other living things (Jariwala et al., 2017). Noise, which is generated as a result of urbanization, increasing industry, traffic density, and the use of electronic and mechanical devices, has turned into an environmental form of pollution (Kaya and Dalgar, 2017; Yuan et al., 2019). This can lead to several disorders in humans such as hearing loss, behaviour and sleep disorders, depression, stress, circulatory disorders, increased blood pressure, respiratory problems, reflex disorders, etc. (Murphy and King, 2011; Anees et al., 2017). According to World Health Organization reports, environmental noise has been evaluated as one of the most important environmental stressors negatively affecting public health, and it has been reported that the quality of life of a large number of people in Europe has been affected by noise (Basu et al., 2021). Therefore, noise has ceased to be a trivial problem and has become one of the main targets to be controlled by central and local governments (Morillas et al., 2018).

Turkey, like many developing countries, has been undergoing significant urbanization since the middle of the twentieth century, and noise levels have risen in tandem. While there was a slow growth in terms of urbanization between 1927 and 1950 in Turkey, 25.1% of the total population in 1960, 33.3% in 1970, 45.4% in 1980 and 75% in 2008 began living in the cities (Ozturk and Caliskan, 2019). Therefore, it is essential to identify and solve urban problems in order to ensure urban sustainability (Hastemoglu and Ozgen, 2006; Ardahanlıoğlu et al., 2020). When compared to rural areas, noise exposure has been much more effective due to the fact that there are more concrete surfaces in cities, the deconstruction is horizontal and vertical, there is less distance between structures, and there are more noise sources. Noise occurs in almost every aspect of our daily lives, especially in large cities (Esmeray and Eren, 2021). Noise is present in trading and industrial facilities, land-sea-airway traffic, avenues and streets, entertainment venues, schools, hospitals, airports, shopping centres, parks, in short, all the places where a brief human life exists (Mohareb and Maassarani, 2019; Xu et al., 2019). From the point of view of human and environmental health, it is very important that noise is kept under control and within the established standards (Da Paz et al., 2018), periodic noise measurements are made for this purpose, and the impact area of noise is determined (Morillas et al., 2021). In order to manage noise pollution, which is seen as the second most dangerous cause of the environmental disease after air pollution (Morillas et al., 2018), it is necessary to determine the impact areas of noise levels, determine population exposure, identify noise sources, develop prevention and management strategies at their source, create control and supervision mechanisms. The first and most important step in this context is the detection of noise and the determination of impact areas through mapping.

The creation of noise maps is important for noise management and the development of preventive strategies. These strategies are necessary for the health of the population exposed to noise. Noise maps designed as an important management tool are priorities for identifying the area under consideration accurately, for identifying noise sources, and taking necessary precautions within this scope (Gonzales et al., 2007; Armah et al., 2010). These maps act as the main tools to carry out research and decision-making in the implementation of action plans to reduce noise pollution (Bocher et al., 2019). Noise measurements and noise maps generated as a result of these measurements provide a good spatial representation of the noise levels in the area and generate healthy data in terms of management-supervision-control mechanisms (Paschalidou et al., 2019). Various data such as noise source, measurement method, measurement time, environmental factors, etc. should be evaluated together for noise mapping (Farcaş et al., 2010; Ahmed et al., 2021). Thus, analysing all this data through the Geographic Information System (GIS) makes it faster and easier to produce noise maps (Abramic et al., 2017).

As it is known, urban centres are areas where society has a large mobile population (Ahmed et al., 2021). The noise generated in these areas is highly effective on the population exposed to it (Mishra et al., 2021). The old town centre of Antalya, which is the fifth-largest city in Turkey in terms of population and has the highest tourist mobility, has been selected as the study area. Turkey's noise directive (Environmental Noise Assessment and Management Regulation, 2010) states the need to draw up noise maps in areas of the settlement that are considered urbanized with over a hundred thousand people, and where the population density is more than 1,000 people per square kilometer.

The study creates a base map for the generation of the noise map, primarily utilizing satellite images of the city centre. Using GIS technologies, these maps have been digitized and measurement points with equal distribution throughout the city have been determined using a numerical map. From these measurement points, the sound levels of the same period were measured with the help of a decibel meter, and the sound levels were coordinated on a numeric map. The method of interpolation is applied to the data achieved. By reclassification, the boundary values are defined and mapped according to the corresponding noise rule. Land survey was carried out again in locations where the limit values specified in the rule were exceeded, and solutions were developed to eliminate the noise by discovering the sources of noise. In this context, the aim of the study is to map the noise pollution in cities, determine the impact areas, determine the noise sources and develop noise prevention strategies. For this purpose, it is envisaged that the results obtained from the study will be an important guide for local authorities in terms of supervision, control and implementation.

MATERIAL AND METHOD

Study area

The main material of the study is the Kaleici region in the city centre of Antalya, Turkey. Antalya, located in the Mediterranean region, is surrounded by the Mediterranean Sea to the south and the Taurus Mountains to the north. The neighbouring provinces bordering Antalya are Mugla, Burdur, Isparta, Konya, and Icel from west to east. The Kaleici district selected as the study area is located at the coordinates of 36°53'4.94"N and 30°42'14.34"E (Figure 1). The district, located at the intersection of the city centre and the sea, is especially heavily used due to its historical and touristic importance.

Figure 1. Location of the study area

Kaleici region is a touristic region transformed into an entertainment centre by preserving the authenticity of streets and houses on a 42 hectares area. There are restaurants, cafes, bars, accommodation facilities, shops, bazaars, and a marina for tourism in Kaleici, and it has become a centre of attraction for local people as well as foreign tourists. Kaleici sits on steep natural cliffs 20-30 meters from the sea. Tophane Garden, Youth Park, Karaalioglu Park, and Atatürk Park in and around Kaleici settlement are located on these cliffs. The surroundings of Kaleici are bordered by Hukumet Street and Atatürk Boulevard. There are many structures such as Yivli Minaret, Clock Tower, Kesik Minaret, which are the symbols of Antalya, as well as historical monuments such as city walls, churches, mosques, masjids, inns, madrasahs, baths, and monuments in the Kaleici region. The historical traditional house architecture and the territory are in harmony with nature. In addition to religious structures such as masjids and tombs, monumental structures such as hammam's, madrasas, walls, towers, and city gates, as well as historical houses reflecting Ottoman times are important structures in Kaleici.

Data preparation

Aerial photographs and satellite images, digital data sets and noise measuring devices were used as auxiliary materials. RS and GIS technologies are often used in particular in the monitoring and analysis of the environment (Musaoglu et al., 2015). These technologies are considered to be an important tool for fast and effective decision-making, and the data generated and analysed from them act as a guide for decision-makers and practitioners. The study used Sentinel 2A satellite images, which are open access as a raster data set. SENTINEL-2 carries an optical sensor with a spectral band of 13. The designed sensor covers four bands with a spatial resolution of 10m, six bands with a resolution of 20m, and three bands with a spatial resolution of 60m. The scope of the study included R-G-B bands with a spatial resolution of 10 m from these bands (Table 1).

A composite process was applied to the bands, an atmospheric correction process was carried out, and geo-referencing was performed. The resulting map has been made ready for use as base data. Then, a grid system was created on the map by using the ArcGIS 10.4 software, and noise measurement points are marked and their coordinate is determined with uniform distribution across the study area.

Table 1. Sentinel 2 used bands and technical specifications (ESA, 2021)

Sentinel 2- Bands	Wavelength (μm)	Resolution (m)
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10

Method

The study method consists of the following four stages: digitization, analysis and evaluation after the data preparation stage (Figure 2).

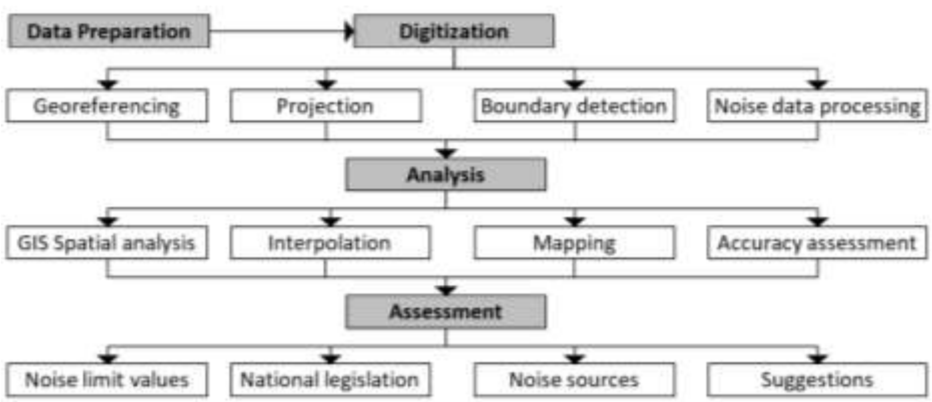


Figure 2. Method flow chart

At the digitization stage, coordinate and projection arrangements of the produced map were made by georeferencing, and in this context, WGS 84 UTM Zone 36 N was used. The boundaries of the study area were determined by considering the highway that surrounds the Kaleici region and provides connections with other regions. Then, a sample was collected from the study area using a decibel meter from the sound measurement points determined according to the grid system created on the map. The technical specifications for the decibel meter used are given in Table 2.

Table 2. Decibel meter and its technical features

Type of Device	**Type 1 sound level meter IEC 61672:2002**
Model of Device	SVAN 971
Measuring Range	15 – 140 dBA
Frequency Weight	A, C, Lineer, Impulse

In this context, coordinates and voice data were taken from 250 points covering all streets and alleys in the region and stored in the database again (Figure 3). The measurements were made in accordance with the criteria specified in the "Environmental Noise Assessment and Management Regulation" in the national legislation. Data collection was carried out between 20 February 2020 and 23 February 2020, during the 20:00-24:00 time frame when the noise generated by places of entertainment was high. Measurements were taken with a decibel meter from a height of 1.5 meters from entertainment venues and other areas located in Kaleici. The acquisition of noise data from a height of approximately 1.5 m in determining the environmental sound level is considered ideal (Blasco et al., 2017). Since it was thought that it would be useful to interpret the audio source during the evaluation stage, each data point was also photographed.

Kriging Interpolation

At the analysis stage, audio data taken from 250 points were transferred into the database in a coordinated manner. For the attribute table of each point, a dBA column was formed and audio data received from that point was entered in the corresponding column. An interpolation method is used to evaluate the spread and distribution of the related sound level data specific to the study area. Beginning with the defined or received value points, interpolation, which is a numerical analysis method, was preferred within the scope of the study as it is a set of methods that are used to find/predict a possible value at a point that is located in a different place between these points and whose value is unknown. Kriging interpolates using data-independent weights. So, in practice, weights from the first estimate can be used for all data sets. Furthermore, it is an 'absolute' interpolator, meaning any prediction at the observation point is the observation itself. In this context, it offers some advantages over other interpolation techniques (Shukla et al., 2020). In the literature, interpolation methods such as Kriging and IDW are usually preferred for noise analysis (Can et al., 2014; Harman et al., 2016; Zou et al., 2016; Aumont et al., 2018). Compared to other interpolations methods, the most distinguishing characteristic of the Kriging method is the fact that it can calculate a variance value for each predicted point or area. IDW uses a simple algorithm based on distance, but the kriging weights come from the semi variogram, which studies the spatial structure of the data (Harman et al., 2016). In case that there are places close to each other in terms of distance and data shows little variability, semi-variogram is preferred (GISGeography, 2021). Since the calculation of a variance value for each measurement point is an indication of the confidence level of the estimated value, the ordinary kriging interpolation method and semi-variogram model were used in this study (Shukla et al., 2020). The basic equation (Cressie, 1993) used in Ordinary Kriging (1) is:

$$N_P = \sum_{i=1}^{n} P_i * N_i \tag{1}$$

Here;
n= the number of points making up the model
Ni= Undulation values of the points used in the calculation of N
NP= Desired undulation value
Pi= Weight values for each Ni value used in the calculation of N.

The equation used here is similar to the equation used in IDW interpolation. The difference is that the weight is not only based on distance but on the semi-variogram (Harman et al., 2016; Shukla et al., 2020). The semi-variogram function can be estimated using remotely sensed data or location data and can accurately model the spatial dependence of each point on its neighbour (Curran, 1988). The empirical semi-variogram provides information on the spatial autocorrelation of datasets and provides functions such as circular, spherical, linear, etc. for the model selection of the empirical semi-variogram (Bohling, 2005). In the scope of the study, the validation results of semi-variogram models were compared for the selection of the model (Table 3). As a result of the fact that the average value is closest to 0 and the standardized mean square root value is closest to 1, the linear semi-variogram model was chosen.

Table 3. Comparison of empirical semi-variogram models

Model	Mean	Mean Square Root	Standardized Mean Square Root	Average Standard Error
Circular	0,026	5,09	0,989	5,15
Spherical	0,025	5,088	0,989	5,14
Linear	**0,022**	**5,045**	**0,990**	**5,08**

As the mean value is closest to 0 and the standardized root mean square value is closest to 1 and at the same time the sound sampling points are chosen by the user (GISGeography, 2021), the linear semi-variogram model was preferred in this study.

Assessment by legislation

During the evaluation stage, the noise values are interpreted for a specific area depending on the interpolation map. Noise measurement results are compared according to the provisions and limit values set in the Environmental Noise Assessment and Management Regulation The relevant regulation entered into force by being published in the Official Gazette No. 27601 on 4 June 2010. This regulation is based on the 14th article of the Environment Law dated 9/8/1983 and numbered 2872 and the subparagraph (b) of the first paragraph of the 9th article of the Law on the Organization and Duties of the Ministry of Environment and Forestry dated 1/5/2003 and numbered 4856.

RESULTS AND DISCUSSION

In the study conducted in the Kaleici district of Antalya province, one of the most important tourist destinations in Turkey, noise data were collected from 250 locations with homogeneous distribution across the area (Figure 3). Data collection was carried out between 20 February 2020 and 23 February 2020, during the 20:00-24:00 time frame when the noise generated by places of entertainment was high.

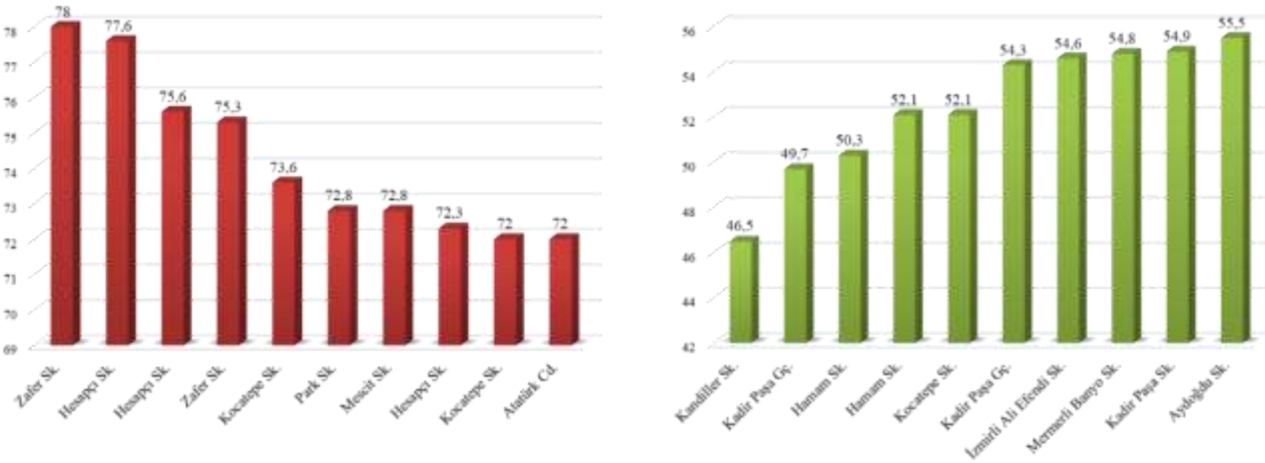
Figure 3. Distribution of noise measurement points

As a noise level, the Leq value, which refers to the equivalent noise level, was measured in dBA. The noise levels of each measurement point with respect to measurements carried out are indicated in Table 4.

Table 4. Measured noise levels

No	Leq(dBA)	No	Leq(dBA)	No	Leq(dBA)	No	Leq(dBA)	No	Leq(dBA)
1	72,8	**51**	61,5	**101**	67,6	**151**	75,6	**201**	66,8
2	68,5	**52**	67,6	**102**	65,9	**152**	56,6	**202**	70,1
3	62,5	**53**	66,3	**103**	55,6	**153**	70,3	**203**	65,9
4	59,6	**54**	61,5	**104**	55,5	**154**	58,7	**204**	59,6
5	49,7	**55**	70,6	**105**	61,0	**155**	59,6	**205**	61,5
6	55,6	**56**	58,9	**106**	60,9	**156**	60,6	**206**	65,0
7	54,3	**57**	66,6	**107**	56,6	**157**	66,6	**207**	68,6
8	64,0	**58**	69,7	**108**	63,1	**158**	59,8	**208**	70,3
9	56,3	**59**	57,8	**109**	62,9	**159**	54,9	**209**	56,3
10	65,0	**60**	60,1	**110**	63,9	**160**	62,1	**210**	60,3
11	64,9	**61**	58,6	**111**	60,1	**161**	59,9	**211**	69,1
12	66,2	**62**	54,6	**112**	57,9	**162**	60,2	**212**	63,7
13	65,5	**63**	60,1	**113**	65,5	**163**	69,8	**213**	58,8
14	58,8	**64**	56,6	**114**	62,3	**164**	71,3	**214**	56,9
15	68,3	**65**	63,5	**115**	60,1	**165**	63,9	**215**	61,8
16	52,1	**66**	70,1	**116**	68,6	**166**	72,0	**216**	59,6
17	56,7	**67**	65,9	**117**	68,7	**167**	70,0	**217**	78,0
18	50,3	**68**	56,5	**118**	60,6	**168**	63,6	**218**	61,2
19	59,8	**69**	63,5	**119**	56,3	**169**	69,4	**219**	65,3
20	56,9	**70**	69,6	**120**	59,7	**170**	61,7	**220**	60,9
21	61,7	**71**	59,1	**121**	62,0	**171**	70,3	**221**	56,6
22	55,8	**72**	61,2	**122**	65,3	**172**	77,6	**222**	63,3
23	61,8	**73**	67,6	**123**	63,4	**173**	70,6	**223**	67,3
24	62,0	**74**	63,9	**124**	60,0	**174**	65,3	**224**	63,4
25	66,7	**75**	67,0	**125**	64,1	**175**	63,3	**225**	62,2
26	46,5	**76**	57,6	**126**	63,3	**176**	68,3	**226**	63,8
27	61,5	**77**	59,3	**127**	56,6	**177**	55,8	**227**	65,2
28	52,1	**78**	63,1	**128**	58,6	**178**	69,3	**228**	70,3
29	68,3	**79**	65,3	**129**	63,1	**179**	64,3	**229**	64,6
30	73,6	**80**	63,2	**130**	69,3	**180**	59,9	**230**	69,1
31	68,8	**81**	63,6	**131**	64,2	**181**	62,3	**231**	69,3
32	67,4	**82**	61,2	**132**	67,6	**182**	69,3	**232**	70,4
33	72,0	**83**	61,4	**133**	63,5	**183**	66,7	**233**	68,6
34	64,1	**84**	66,3	**134**	68,9	**184**	61,3	**234**	60,3
35	65,6	**85**	63,7	**135**	71,8	**185**	60,9	**235**	56,5
36	65,9	**86**	63,2	**136**	72,8	**186**	68,9	**236**	63,7
37	69,3	**87**	57,1	**137**	69,3	**187**	61,5	**237**	62,1
38	63,3	**88**	57,9	**138**	64,6	**188**	60,7	**238**	63,3
39	69,9	**89**	58,0	**139**	70,3	**189**	63,8	**239**	60,5
40	63,4	**90**	59,9	**140**	70,9	**190**	58,6	**240**	59,3
41	61,8	**91**	56,6	**141**	58,7	**191**	65,8	**241**	59,6
42	72,0	**92**	54,8	**142**	59,6	**192**	59,9	**242**	67,0
43	66,8	**93**	56,6	**143**	62,0	**193**	63,1	**243**	57,6
44	59,9	**94**	61,3	**144**	71,5	**194**	60,0	**244**	69,6
45	66,7	**95**	69,1	**145**	63,5	**195**	61,2	**245**	68,6
46	61,5	**96**	62,3	**146**	68,2	**196**	66,8	**246**	67,6
47	63,9	**97**	64,3	**147**	65,3	**197**	69,0	**247**	63,3
48	69,3	**98**	56,6	**148**	69,3	**198**	64,5	**248**	63,3
49	60,2	**99**	59,9	**149**	70,3	**199**	61,8	**249**	61,0
50	69,3	**100**	64,3	**150**	72,3	**200**	71,3	**250**	75,3

LAeq⩽49 dB(A)- clearly acceptable; 49 <LAeq⩽62 dB(A)- normally acceptable; 62 <LAeq⩽76 dB(A) — normally unacceptable; LAeq>76 dB(A)—clearly unacceptable



a b

Figure 4. The streets with the highest (a) and lowest (b) noise levels

The streets with the lowest and highest sound levels according to noise measurements are indicated in figure 4. The lowest noise level was measured at 46.5 dBA and the highest noise level was measured at 78 dBA.

It is seen that the points where the noise level is the highest within the framework of legal legislation are usually the places where the streets are narrow, the walls are high, where the vegetation is devoid of texture, where there are many entertainment venues playing loud music. On the contrary, the points where the noise level is low consist of dead-end streets and areas closed to vehicle traffic, accommodation structures, parking areas, and vacant lots where there is a lot of vegetation.

The noise data obtained were evaluated within the framework of the" Regulation on the Assessment and Management of Environmental Noise" and the limit values specified in Table 5 were taken as a basis. Considering the physical structure of the study area, the limit values for the two classes specified in the corresponding regulation are used.

Table 5. Noise level limit values according to the relevant regulation

Areas	L_{day} (dBA)	$L_{evening}$ (dBA)	L_{night} (dBA)
In areas where commercial buildings and noise-sensitive uses exist together, areas where residences are concentrated	65	60	55
In areas where commercial buildings and noise-sensitive uses exist together, areas where workplaces are concentrated	68	63	58

According to the noise measurement values performed in Kaleici within the scope of areas where residences are concentrated from among the areas where commercial buildings and noise-sensitive uses exist together, it was determined that 67 measurement points were below the Levening limit value of 60 dBA, and 183 measurement points were above this value. Within the scope of areas where workplaces are concentrated from among the areas where commercial buildings and noise-sensitive uses exist together, it has been determined that 91 measurement points are above the relevant limit value. The noise level map modelled based on the relevant limit values in accordance with the obtained data is given in Figure 5.

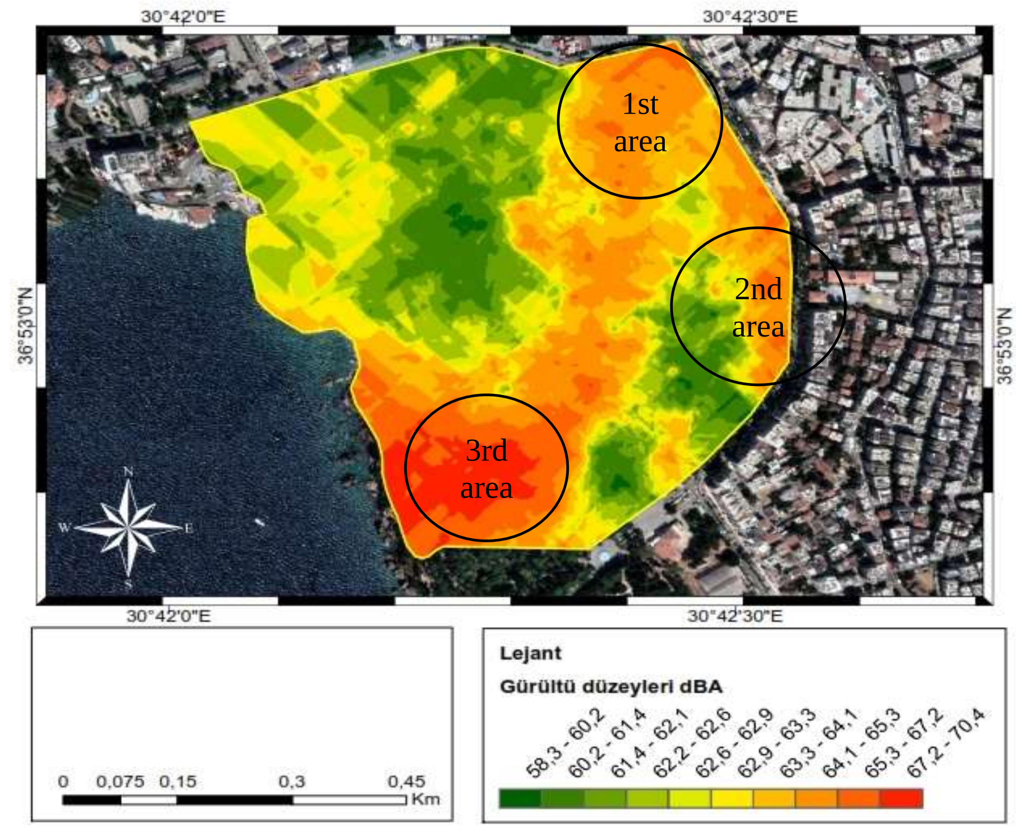


Figure 5. Study area noise level model

According to the noise level map created for the Kaleici region, the parts where the noise is above the limit values were divided into three main regions and evaluated. In general, the corridor connecting the first region and the third region are heavily used areas where there are tourist entertainment facilities. The corridor connecting the first region and the second region is the part where the noise caused by the highway is intense. In terms of the map produced, the parts where the noise is below 60 dBA are rich in green textures and partly lacking workplaces. The 1st region has a high level of noise due to the noise caused by traffic and intersections, being the entrance area of Isiklar street, being exposed to crowds of people and intense activity in the food and beverage places known as Donerciler bazaar, entertainment venues performing live music, crowds of local and foreign tourists and shops. The 2nd region has a high noise level due to, in addition to the road traffic noise originating from Atatürk Street and Isiklar Street, the tram line passing over these streets, the existence of entertainment places such as cafes and restaurants with live music, the crowd of people walking on the streets, the phaeton route and the noise caused by the shops. The 3rd region has a high level of noise due to environmental noise caused by intense live music activities in places such as bars, discos, taverns, restaurants, which are mostly entertainment venues, positioning the tables and chairs of entertainment venues on the streets, the noise from the traffic even though not as intense as the Işıklar street, roads being heavily crowded by tourists. Due to the absence of noise caused by road traffic, the presence of open and green areas, the operation of places such as hotels, hostels, apartments used for accommodation as noiseless businesses, and the presence of residential areas, in the areas indicated by the colour green have an average noise level and are below the noise threshold specified in the relevant legislation.

The findings of study suggest that the Kaleici region, which is one of Antalya's busiest tourist destinations, has a noise level that exceeds the noise limit value set by the relevant legislation. It is understood that a significant part of the high noise level in this region is caused by noise from workplaces and traffic.

Noise pollution, one of the most important environmental factors in urban environments, is considered a major problem affecting the quality of life of residents (Masum et al., 2021). Noise affects people exposed to it both psychologically and physiologically (Moudon, 2009; Murphy et al., 2009). Noise pollution, especially in the evening, can also negatively affect social behavior in humans (Gidlöf-Gunnarsson and Öhrström, 2007). As a result, the high noise level determined as a result of the study is higher than the limits specified in the relevant legislation, which adversely affects the city and the citizens. The US Department of Housing and Urban Development (HUD) recommends noise levels measured outdoors for residential areas as follows: LAeq⩽49 dB(A)- clearly acceptable; 49 <LAeq⩽62 dB(A)- normally acceptable; 62 <LAeq⩽76 dB(A) — normally unacceptable; LAeq>76 dB(A)— clearly unacceptable (Zannin et al., 2002). In this context, both national legislation and international noise limit values overlap, and the high value is considered unacceptable. In this context, it is important to develop strategies to reduce the high noise level in the study area.

In order to reduce noise pollution, prevention, control, and supervision steps at the source should be implemented in the study. For prevention at welding, the source that causes high noise should be replaced with one that creates less noise, the use of electric vehicles should be expanded and noise measurements should be carried out continuously and regularly, and the control of relevant sound level range should be ensured. The phase of noise control can be divided into structural and plant solutions. Structural measures that can be taken against noise pollution include the application of reinforced concrete noise curtains in sound sources, keeping noise sources from industry and highways separate from living spaces during urban planning, giving more importance to acoustics in architecture, improvement of wall insulation of dwellings of noisy workplaces, and the mandatory use of sound insulation materials in building and construction work.

The following structural elements can be used to reduce the noise levels found in the Kaleici area: Soundproofing materials under the floor parquet, sound insulation sponges, acoustic barrier sponge, acoustic felts, sound insulation tapes, acoustically insulated doors. The application of structural measures to isolate the sound in the interior of noisy spaces that are at an uncomfortable level prevents the sound from coming out and can significantly reduce the environmental noise level. Herbal precautions that can be taken against noise pollution are herbal noise curtains, the use of shrub group fence plants, preference of plants with dense leaves, and the planting intervals of the plants being more frequent and the lengths being longer. According to Yazgan and Erdogan (2007), plant materials have a significant effect on reducing and distributing sound. Tall, thick, and broad leaves can be preferred as they are more effective in reflecting and absorbing sound. According to Finke (1980), the plants preferred to reduce noise have these attributes: These plants should be high, have a dense leaf structure, have rather large and hard leaves, be evergreen species in winter, their leaves should be arranged perpendicular to the direction of the sound and overlap each other, they should have dense branch and leaf texture up to the ground, and the rows of plants should be frequent. Since the branches and leaves of trees operate as a barrier to reflect, refract, disperse, mask, and absorb sound waves, their usage as a noise-reducing material is critical (Azkorra et all. 2015). Therefore, the use of such plants in the Kaleici region needs to be extended. Since it is known that vegetative noise screens reduce the noise level by 10 dBA (Fang and Ling, 2003), the use of noise screens in the region should be widely increased. Given that the bush in the right form and range also reduces the noise level by approximately 6 dBA (Kocbeker ve Onder, 2012), it is predicted that the appropriate use of shrub-shaped plant materials within the scope of landscape planning in the study area can significantly reduce the high levels of noise. The use of vertical gardens should be expanded as Kaleici Region, in particular, stands out with its narrow streets and entertainment venues (Figure 6).

Figure 6. Vertical garden examples for noise reduction

The third measure to prevent noise levels is carrying out environmental inspections. The most important step in this situation is to raise noise awareness in people. Among the administrative measures that can be taken against noise pollution are the following: establishing systems that will ensure regular monitoring of high-noise places, keeping the increase in the number of vehicles under control, preferring motor vehicles that produce less noise, preventing unnecessary honking of motor vehicles, operation of public entertainment venues in settlements in accordance with the regulations made, preventing electronically amplified musical instruments from being at a level that would disturb the environment in public places and residential areas, and the volume of live music, radio, television, and musical instruments not being raised to a disturbing level at home or entertainment venues. Frequent use of inspections and the introduction of deterrent penalties for businesses that exceed the noise levels may be cited as suggestions.

CONCLUSION

Rapid urbanization and changing land use patterns (Singh and Kalota, 2019) are important factors affecting noise pollution. In this study, which was carried out to measure and map the environmental noise level, based on the noise limit values determined by the provisions of the national legislation, it is seen that the Kaleici region has high noise values. Noise sources are often attributed to traffic as well as to entertainment and workplaces. The areas where noise is often densely populated, according to the mapping process on GIS, are often areas with a high level of noise. These zones consist of narrow streets and concrete surfaces. They are also very weak in terms of plant material. It would be helpful to keep the noise level in the region within the required limits by implementing administrative restrictions within the legal framework, first keeping the noise under control, and then conducting landscape design studies with structural and vegetative solution options.

Updating and maintaining the map created as a result of the modelling is critical. The accuracy and continuity of the population information, tourist number information, structure, and land information of the people living in Kaleici should be kept under regular control and monitored. Changes to the Kaleici region and businesses should be considered. The properties and data of the noise sources must be updated and the noise levels maps prepared for this region must be revised according to current results. Monitoring the businesses that cause environmental noise, making noise measurements at certain time intervals, obtaining permits within the scope of Environmental Law and other environmental legislation, imposing sanctions on businesses that do not have a permit or exceed the noise limit values are very critical issues in terms of controlling environmental noise.

As a result, in order to reduce noise pollution caused by various reasons in the Kaleici region, it is necessary to implement legal regulations, and to ensure the continuity of controls and inspections. An entertainment business that broadcasts live music must first obtain live music permission according to the provisions of the Regulation on Opening a Business and Working Licenses and Environmental Noise Assessment and Management Regulation Article 24, which states "Within the scope of this article, entertainment venues or venues that can perform live music must obtain live music permission in accordance with the provisions of the Regulation on Business and Working Licenses, which was put into effect with the Council of Ministers Decision dated 14/7/2005 and numbered 2005/9207. While this permit is granted, the appropriate opinion of the authorized administration regarding the principles specified in this article is taken, if necessary, the competent administration prepares an Environmental Noise Level Assessment Report and the relevant opinion of the responsible administration regarding the report is used as a foundation." Pursuant to this article, a live music permit is required. Noise levels will be reduced as businesses are encouraged by relevant institutions to receive live music permission and again as a result of training and awareness activities regarding noise being provided to managers and employees by businesses with live music permits.

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