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Seasonal Change and Spatial Distribution of Traffic Noise in Seferihisar, Turkey

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In this study, traffic noise in Seferihisar, which is a holiday resort by the Aegean Sea in the West of Turkey, was investigated. The noise occurring in summer and winter, on weekdays, and at weekends was mapped separately. Besides, land uses exposed to traffic noise were specified. In the carried out method, the land uses were primarily mapped by using the satellite images of the study area. Then, the noise was measured at 46 points during ten days in summer and winter, on weekdays and at weekends, and it was mapped by using Inverse Distance Weighting (IDW) method and by means of Geographic Information System (GIS) techniques. The measurements were taken in the daytime (07:00–19:00), in the evening (19:00–23:00), and at night (23:00–07:00) as stated in the Turkish Regulation of Assessment and Management of Environmental Noise. Since the time interval of the daytime measurements was large, the noise was measured in three different periods for the daytime measurements. In the formation of noise maps, logarithmic averages of all measurements taken at each point were used. The noise maps were overlapped with the land use maps by the help of the GIS techniques; the land use affected by the noise was analyzed.

The results showed that the road traffic noise varied from summer to winter seasons in the study area depending on heavy or light traffic. The noise occurring in summer showed an increase both on weekdays and at weekends. While the limit value was exceeded in 49 of the measurement averages taken in winter, the limit value was exceeded in 96 measurements taken in summer. The noise maps formed according to the IDW method displayed that the areas in which the limit value was exceeded in the daytime in summer took up 14.27% of the study area while this rate went down to 4.06% in winter. The study area is one of the most important destinations for summer holiday. 20.12% of the area that exceeded the limit value in summer was builtup and 10.69% of them was tourism area. The noise together with population and traffic that increase in summer season is an important environmental problem against which some precautions should be taken. The findings of the study present significant results which might guide local governments in preventing and managing the noise.

Keywords: noise map; IDW; GIS; traffic noise.

1. Introduction

Highways are the major investments in which human and environment have been in interaction at the most intensive level. Highways affect natural and sociocultural environment differently in both rural and urban areas. Especially, the noise that occurs in urban areas based on traffic volume is a kind of pollution, influencing the quality of life directly in today's cities. Moreover, it is the primary problem, which requires indispensable solutions (Murphy, King, 2014; Goldsmith, 2012; Zannin *et al.*, 2002; 2003; Berglund *et al.*, 1999; Arana, Garcia, 1998). 90% of passenger transportation and cargo are carried out via highways in Turkey (Çolakkadioğlu, Yücel, 2017). Although investments on subway have been started in several metropolises in recent years, motorized vehicles are still preferred mainly in urban transportation. For this reason, preparing noise maps and action plans according to these maps are of vital importance to determine the noise stemming from traffic and taking control precautions in every part of Turkey.

Noise influencing daily life comfort negatively affects life not only in metropolises but also in holiday resorts where people go to relax. Traffic noise becomes one of the most important environmental problems in holiday resorts depending on the number of vehicles increasing especially in tourism seasons. Seferihisar, the research context of this study, has been one of the towns struggling with this problem intensively in the recent years.

Seferihisar was accepted as a member of the International Assembly of Cittaslow (Slowcity) Association in 2009 because the local natural, cultural and historical richness of the Turkey was protected there. It is also the first holiday resort with the title of slow city in Turkey. There are 71 criteria in the declaration of the association, which aims to struggle with the fast change in urban life. The process of becoming a slow city is carried out with the volunteerism of the local government intending for the maintenance of a calm urban life. Local governments are obliged to apply the criteria which are available in the declaration of the association for the protection of identity components of the town and a calm, slow daily life. One of these criteria is the measurement of the noise in the city and reduction of the existing noise.

Identifying the noise levels and preparing noise maps to take the necessary precautions have been in practice in many countries in the recent years. Especially after the EU Environmental Noise Directive 2002/49/EC (European Commission, 2002) had been put into force, the member countries became obliged to prepare noise maps and noise management plans every five years. There are generally two main purposes of preparing noise maps. The first one is to determine the noisy areas and to find out how many people are affected by these areas. The second one is to determine the precautions to reduce noise and constitute suitable action plans in line with these precautions. Most of the research to date has showed plenty of noise mapping studies carried out in towns in various parts of the world. In some of these studies, softwares such as Cadna A and Sound PLAN were benefited from during the preparation of noise maps (Suárez Barros, 2014; Çolakkadioğlu, Yücel, 2017). Some studies compared the methods which are used to prepare noise maps. These studies focused on the advantages and disadvantages of above mentioned methods with the help of sample implementations (Can *et al.*, 2014; Harman *et al.*, 2016). In the literature, there are various studies that special techniques applications of GIS have been employed to map, monitor and model noise (Akintuyi *et al.*, 2014). Some of these studies, which claimed the advantages of making use of GIS techniques in preparing noise maps, were also included in the previous studies. According to these studies, GIS is a tool, which makes a great contribution in preparing noise maps (Li *et al.*, 2002; de Kluijver, Stoter, 2003; Cai *et al.*, 2015; Yilmaz, Hocanli, 2006).

The purpose of this study is three-fold:

1) to determine the traffic noise which arises in especially summer months in line with increasing tourism,
2) to reveal the noise level differences in summer and winter in the town,
3) to designate the types of places exposed to the noise pollution in which noise limit values are exceeded.

Concerning this purpose, noise maps showing the level of noise in the town in summer and winter months were generated.

2. Methodology

2.1. Study area

The study was conducted in Seferihisar within the borders of İzmir province, in the west of Turkey between $26°45'00'' - 26°53'00''$ eastern longitudes and $38°7'30'' - 38°13'30''$ northern latitudes. The study area consists of two groups of construction; the center of Seferihisar and the neighborhood of Sığacık 5 km west of the town center (Fig. 1). The population of the town is 36335. According to the data obtained from the municipality, it is predicted that the population goes up 2 or 3 times in tourism season and at weekends (Seferihisar Municipality, 2015). The most important economic sectors in the field are tourism and agriculture.

The study area located in the Mediterranean Climate Zone is hot and dry in summers and warm and rainy in winters. The average temperature is above 20°C in summer months (June – July – August – September). The average annual rainfall is 599.5 mm. When altitude zones of the town of Seferihisar, which is by the Aegean Sea, and its neighborhood are taken into account, it is seen that it has an altitude zone going up to 245 m starting from the sea level. Seferihisar is located on a plain area with slope ranging from 0% and 2%. As presented above, Seferihisar received the title of slow city and became a member of International Assembly of Cittaslow Association in 2009 because of its natural and cultural characteristics. Since then, the number of visitors coming to this town in holiday seasons has increased even more.

2.2. Data sources and data preparation

2.2.1. Land uses

In the study area, WorldView-2 satellite image with a resolution of 50×50 cm of the area was classified to define the land uses that might be affected by the noise.

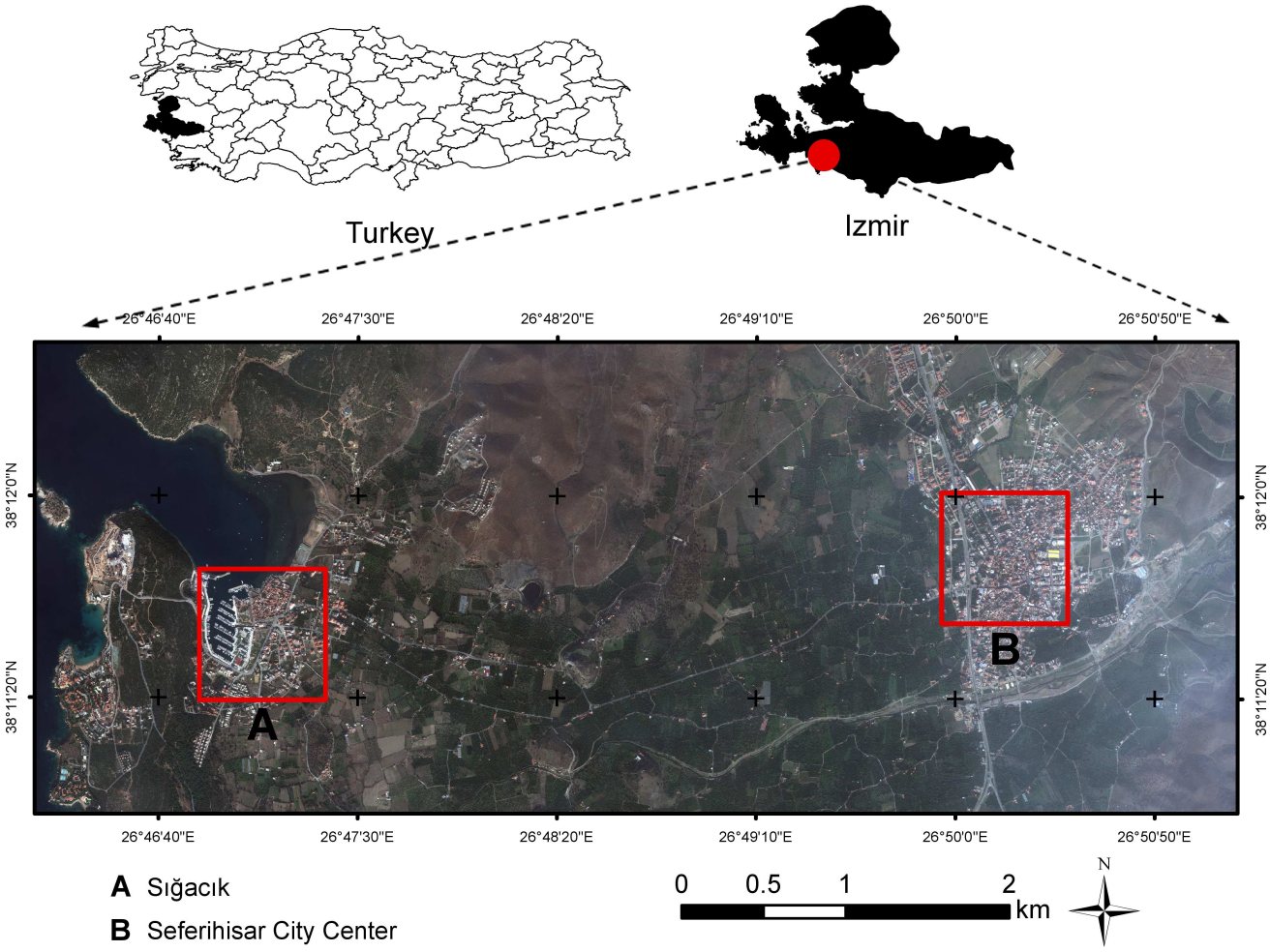

Fig. 1. Geographic location of Seferihisar.

Classification is based on CORINE terrain classifications (EEA, 1997) and the land uses that are defined by The Turkish building law no. 3194. In line with this, the study area was classified into five groups:build-up, tourism area, trading area, green urban area and agricultural area. In this study, supervised classification method was used for the land use classification (Werner *et al.*, 2014; Johnson, Iizuka, 2016). Field data were collected using GPS to assess the classification accuracy. The results of kappa statistics used for evaluation of classification results were calculated as 0.92.

2.2.2. Noise measurement approach

In order to analyze the noise level of Seferihisar, 25 measurement points in the center of Seferihisar and 21 measurement points in Sığacık (in total 46 measurement points) were determined (Fig. 2). Traffic volume was taken into consideration while determining the measurement points. At those 46 measurement points, the maximum noise levels ($L_{\max}$), minimum noise levels ($L_{\min}$) and equivalent noise levels (L_{eq}) were measured via using Delta OHM HD2010UC sound measurement device for 10 days. The measurements were taken in the study area by three different equipment and teams. The coordinates of the points at which measurements were taken were determined by Garmin eTrex Legend® HCX GPS device and they were transferred onto land's digitized satellite image by GPS Track Maker software. The measurements were done according to the standards of ISO 1996-1 (2003) and ISO 1996-2 (2007). The measurements were done at 1.5 m high above the ground levels for 10 minutes. During the measurements of the noise, any formation of noise that might interfere the measurement results was prevented. The calibration of the device was done before each measurement.

In the study area, there are important changes in population depending on the daily and seasonal tourism activities. For this reason, noise maps were prepared separately for the winter (December), the summer (July), weekdays, and weekends. Weekday measurements were completed from Monday to Friday during two weeks. Weekend measurements were done on Saturdays and Sundays. The measurements were done at each point for 10 days.

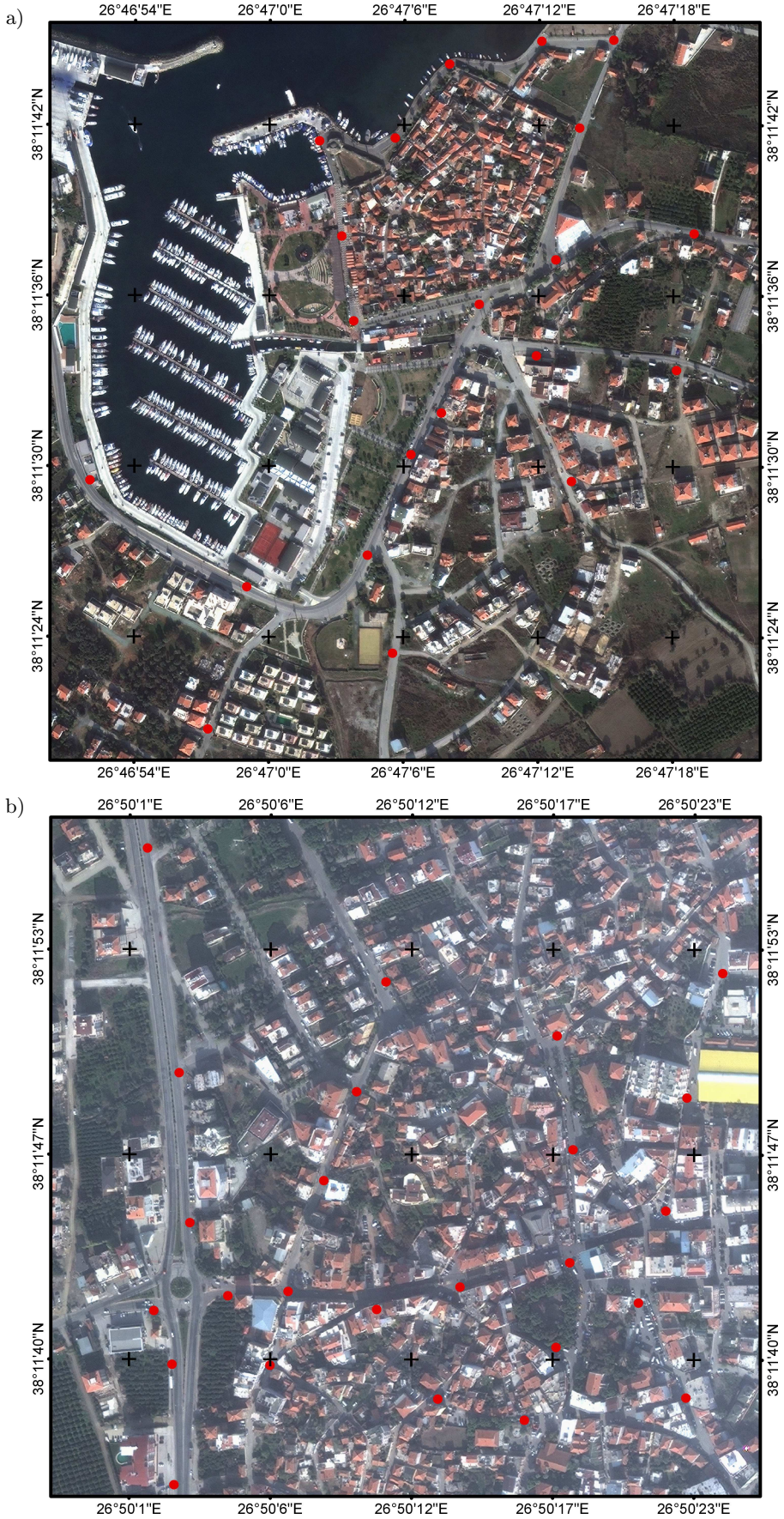

Fig. 2. Noise measurement locations: a) Sığacık, b) Seferihisar city center.

Table 1. The noise limit values for roads in Turkey (Official Gazette, 2011).

Land use type	Planned/restored roads			Existing roads		
	L_{day} [dB(A)]	$L_{evening}$ [dB(A)]	L_{night} [dB(A)]	L_{day} [dB(A)]	$L_{evening}$ [dB(A)]	L_{night} [dB(A)]
Noise-sensitive areas where educational, cultural, health institutesor summer residential and camping areas are predominant	60	55	50	65	60	55
Noise sensitive areas and commercial areas (predominantly residential)	63	58	53	68*	63*	58*
Noise sensitive areas and commercial areas (predominantly commercial)	65	60	55	70	65	60
Industrial area	67	62	57	72	67	62

*The values used in this study.

The measurements were done at times which were determined by the Turkish Regulation of Assessment and Management of Environmental Noise. The measurement intervals were at three different time periods, in the daytime (07:00–19:00), in the evening (19:00–23:00), and at night (23:00–07:00). In this study area, noise maps were prepared separately for the daytime, the evening, and the night.

As the daytime measurement interval was long, the measurements were taken in three different time periods: the morning (7:00–9:00), the noon (12:00–14:00), and the afternoon (4:00–6:00) for daytime measurement. For the measurements that were used in the formation of noise maps, the logarithmic average of all measurements at all points was calculated according to the equitation below.

$$L = 10 \log \frac{1}{n} \sum_{i=1}^{n} 10^{\frac{L_i}{10}} \qquad (i = 1, 2, 3, \ldots, n),$$

where L is noise levels, n – number of noise measurement, L_i – noise level of i-th sample point, i – sample point.

Through the obtained data, noise maps were formed by using the IDW interpolation method in Spatial Analyst Module of ArcGIS 10 software. In the analysis and interpretation of the maps, limit values in the related regulation were taken into consideration (Table 1). The noise maps which were formed were overlapped with the land use map and the types of usages exposed to the noise were defined.

2.3. IDW interpolation

Inverse distance weighted (IDW) is an interpolation technique used for the determination of the values belonging to the other cells (Pixel) by the help of the values belonging to the points at which the measurements were taken. The value belonging to the point which will be predicted is a function of the neighbor point at which measurement is taken (Watson, 1992). IDW method uses the measurements at the sampled points to predict the surface interpolation of the noise during the formation of noise maps (Can *et al.*, 2014; Harman *et al.*, 2016)

$$f(x, y) = No = \frac{\sum_{i=1}^{n} N_i w_i}{\sum_{i=1}^{n} w_i},$$

$$w_i = \frac{1}{d_i^k},$$

$$d_i = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2},$$

where No is the interpolated value of a grid node, n – number of points at which measurements are taken, N_i – noise measurement at the i point, w_i – weight of noise values at the i point, k – the weighting power, d_i – the horizontal distance between (x_1, y_1) and (x_2, y_2), (x_1, y_1) – sampled point and (x_2, y_2) – the point to be interpolated.

3. Results and discussion

3.1. Determination of uses in affected zone

The main land uses in the study area were classified into five classes, i.e. built-up, tourism area, agricultural area, green urban area, and roads (Fig. 3). The land uses and land cover in the study area were given in Table 2 after being calculated by GIS methods over a digitized map. A considerable part of the land in the center of Seferihisar (25.51%) is covered with build-up areas. Therefore, the population which is exposed to the noise is higher in this area. In Sığacık, on the other side, a major part of the land is covered with green urban areas used for recreation activities. The noise in this region has a highly negative effect on domestic and foreign tourists who visit the town, as it is known as a slow city.

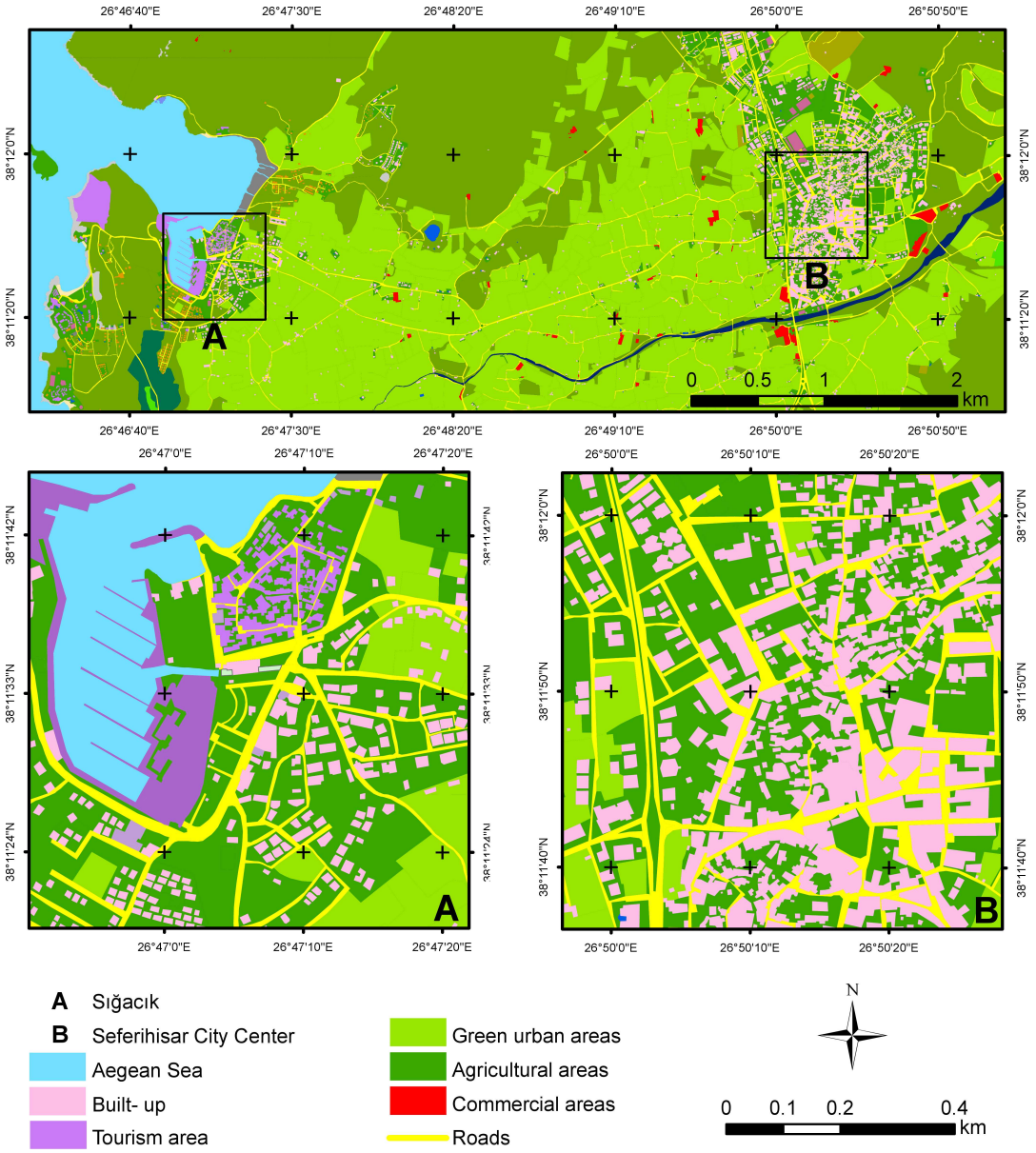

Fig. 3. The land uses in the study area.

Table 2. The distribution of land uses in the study area.

Land uses	Sığacık		Seferihisar city center	
	Area [ha]	%	Area [ha]	%
Roads	6.31	12.66	9.79	15.91
Build-up	4.99	10.01	25.51	35.52
Tourism area	6.82	13.69	0.00	0.00
Green urban areas	24.13	48.43	21.85	41.47
Agricultural areas	7.58	15.21	4.37	7.10

3.2. Noise maps

Logarithmic averages of all measurements taken at measurement points were used in the production of noise maps (Table 3). The lowest value measured was 39 dB(A) and the highest value measured in the study area was 79 dB(A). The measurements exceeded the limit values that are defined in the regulation as 22 points in winter and 24 points in summer. The noise maps produced in the scope of the study were given in Figs. 4, 5. The main noise resulting from the traffic in the center of Seferihisar spreads from the highway of İzmir-Kuşadası. The noise level which goes up to 79–77 dB(A) in summer, goes down to 65–70 dB(A) in Atatürk Street by which the center of Seferihisar can be reached from the main road. An increase in the noise level is observed in both Seferihisar and Sığacık at weekends in summer. It should be underlined that a significant increase in the noise level especially in Sığacık is observed when the noises occurring in the

Table 3. The measured values in study area [dB(A)].

Point		Winter						Summer					
		Weekdays			Weekend			Weekdays			Weekend		
		L_d	L_e	L_n	L_d	L_e	L_n	L_d	L_e	L_n	L_d	L_e	L_n
Sığacık	1	70	54	39	66	50	42	48	51	51	53	60	51
	2	65	64	58	64	65	66	52	56	55	56	70	55
	3	58	51	41	56	47	53	46	45	50	45	54	50
	4	56	49	43	54	55	60	45	43	40	42	53	40
	5	52	44	44	49	49	47	49	49	43	45	42	43
	6	53	44	48	62	47	41	54	50	46	62	63	46
	7	46	45	51	48	43	39	58	59	53	69	64	53
	8	49	51	54	50	46	40	63	66	57	72	70	57
	9	57	54	43	53	56	37	69	70	62	75	73	62
	10	54	48	46	55	51	61	69	72	61	76	74	61
	11	63	58	58	65	55	62	66	69	60	71	72	60
	12	59	49	54	59	55	43	49	42	54	63	56	54
	13	62	50	43	54	43	45	42	41	39	47	47	39
	14	56	55	50	59	48	37	42	41	37	42	43	37
	15	64	59	58	57	55	48	63	68	58	70	70	58
	16	60	57	55	62	60	57	63	67	56	71	68	56
	17	61	52	63	59	44	44	64	67	53	71	69	53
	18	57	46	44	55	54	42	52	52	41	52	52	41
	19	57	55	44	55	50	47	50	54	42	62	62	42
	20	58	52	51	58	46	46	46	46	40	56	54	40
	21	44	41	44	48	55	45	43	42	38	45	45	38
Seferihisar	22	65	59	62	62	62	63	66	67	56	71	73	70
	23	72	66	67	71	63	48	74	67	53	73	73	65
	24	73	66	68	73	61	49	77	65	54	72	72	65
	25	66	61	65	67	65	57	70	68	52	73	73	67
	26	71	62	67	69	61	64	74	70	74	73	73	68
	27	73	64	71	64	70	72	75	71	75	73	71	69
	28	71	70	63	68	71	67	78	73	76	73	74	68
	29	64	53	59	61	55	48	65	55	53	62	61	50
	30	64	55	51	55	54	51	67	65	51	55	58	53
	31	63	63	71	59	59	39	64	63	52	65	63	50
	32	68	62	61	67	64	56	72	68	52	73	68	59
	33	67	63	63	64	65	49	70	67	53	74	68	52
	34	68	61	68	64	68	55	73	63	51	79	70	56
	35	68	60	55	61	61	53	72	61	58	72	63	48
	36	64	54	49	59	56	47	67	60	55	59	59	53
	37	60	53	53	61	53	45	60	55	54	63	55	45
	38	63	56	62	63	64	52	66	65	60	65	65	53
	39	63	55	53	60	52	51	64	58	54	60	55	49
	40	59	58	43	63	53	52	53	61	49	67	59	52
	41	67	57	44	67	60	61	58	59	50	69	64	55
	42	62	52	50	52	52	46	55	50	50	53	59	50
	43	60	50	54	56	54	52	51	52	57	60	61	53
	44	60	58	55	61	54	39	66	63	55	68	65	55
	45	60	47	38	50	43	38	63	50	41	54	46	38
	46	56	60	46	56	57	45	61	60	49	58	61	50

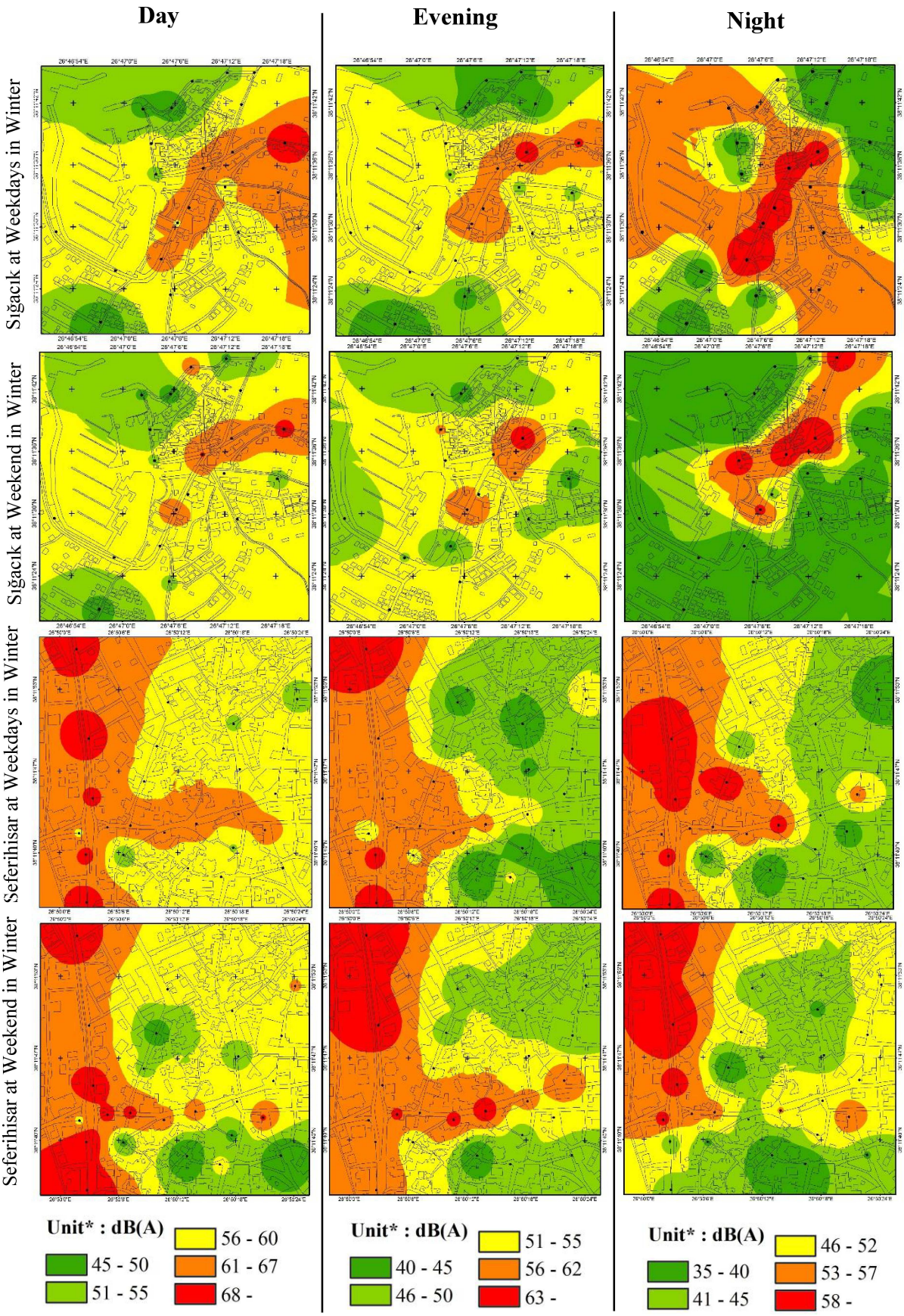

Fig. 4. Daytime, evening and night noise maps of study area in winter period (* the scales based on the noise limit values in Turkey).

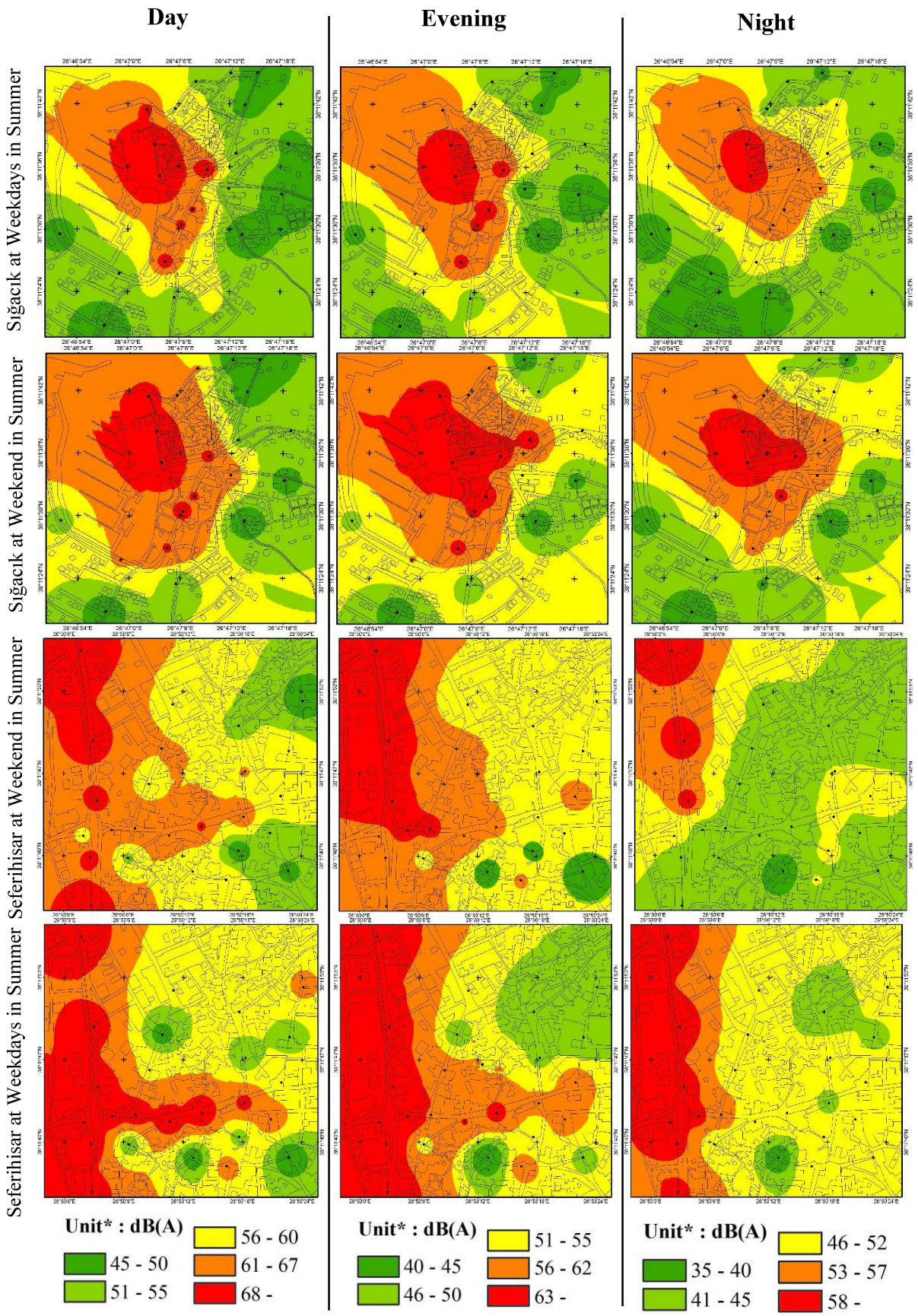

Fig. 5. Daytime, evening and night noise maps of study area in summer period (* the scales based on the noise limit values in Turkey).

summer period are considered. This increase becomes even higher at weekends. The reason of this increase is caused by the rise in the number of tourists visiting the study area at the weekends for day trips.

In the center of Seferihisar, a decrease of 5 dB(A) in the noise level in the evening was observed when compared to the noise level in the daytime in winter. It can be stated that a relative decrease was observed when the noise levels occurred at weekends in winter period. When the noise maps produced for Sığacık in winter were considered, it was seen that daytime noise levels almost never exceeded the limit values. It was also seen that the noise level at weekends decreased further. The reason of this was the decrease in the population in winter in Sığacık, an important destination in terms of summer tourism.

In the scope of this study, the land uses in the study areas in which the noise exceeded the limit values were analyzed. They were presented in Figs. 6 and 7. Outdoor and green areas used as recreational places are on the top of the spaces in which the noise exceeded the limit values in the center of Seferihisar in summer. A substantial part of the population uses these areas

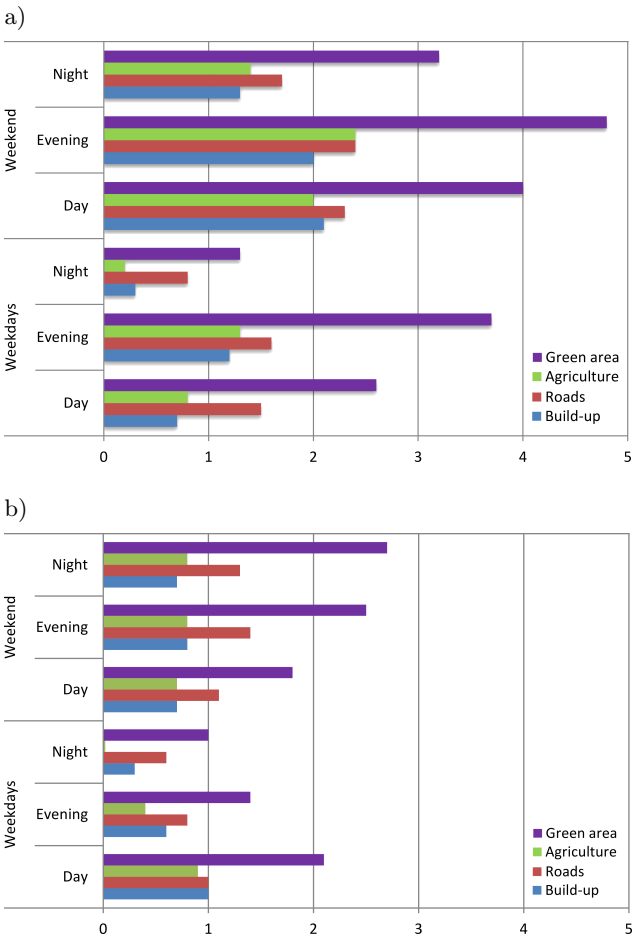

Fig. 6. The land land (area [ha]) uses in which the noise exceeded the limit values in Seferihisar: a) in summer, b) in winter.

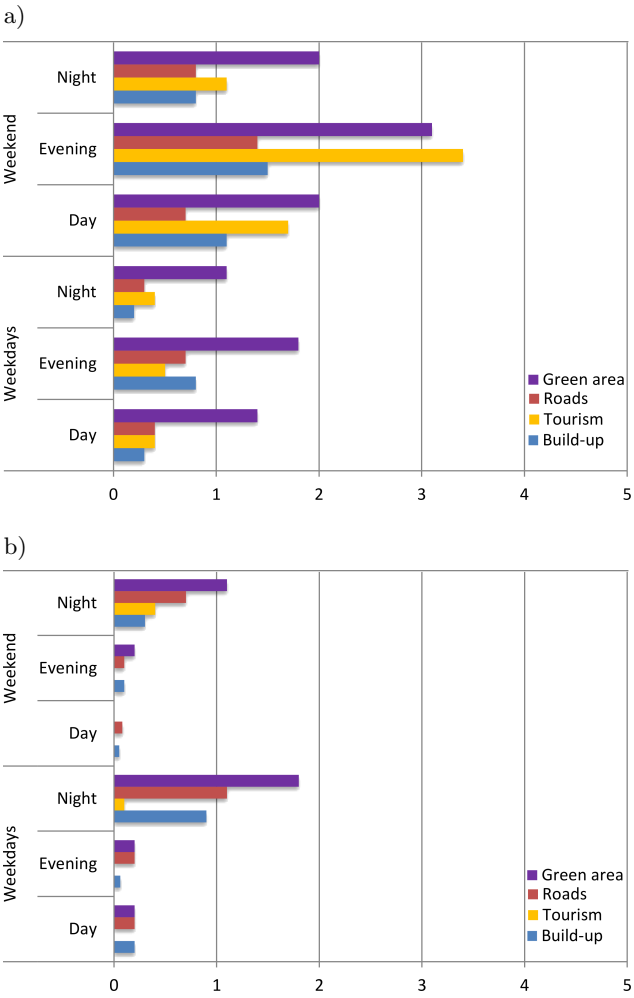

Fig. 7. The land (area [ha]) uses in which the noise exceeded the limit values in Sığacık: a) in summer, b) in winter.

actively especially in hot summer months. The number of areas that is exposed to the noise increases in the evenings at weekends in summer due to heavier traffic. Agricultural and build-up areas are the ones which follow green areas that are affected most by the noise in Seferihisar. As seen in the noise maps, the areas that are affected by the noise in summer in Sığacık are the areas of transportation, agricultural and residential, respectively. In winter, on the other hand, the amount of land uses in which the limit values are exceeded goes down dramatically and almost all of these areas are green and build-up areas.

4. Conclusions

In this study, the seasonal changes of the traffic noise in Seferihisar, one of the holiday resorts whose attractiveness has been increasing in the recent years in Turkey, were analyzed and mapped. According to the results obtained, it is required to check the traffic periodically and take some prospective precautions in Seferihisar, a holiday resort and a slow city.

Fig. 8. Pedestrianization proposal of Atatürk Street.

The results of the noise measurements and observations reveal that there is a massive vehicle intensity on Atatürk Street, which can be regarded as the main reason of the noise in the center of the town. Besides, the existing traffic intensity is contradictory with the town's status of a slow city. Atatürk Street, which is the heartland corridor of the town, is active and occupied with parked cars almost all hours of the day. One of the basic recommendations presented in the scope of the project is closing the traffic on the Atatürk Street till the town square. In this way, a "social life corridor" will be provided for only bicycle lines and walking tracks. This will also help to improve the communication between the town's residents and trigger the cultural life. Within this scope, the urban design proposal should be prepared or coordinated by the local government. An example is presented in Fig. 8.

Within the context of the study, the other recommendations offered to reduce the noise deriving from traffic are as follows.

- In line with the sustainable urban transportation principles, environmental friendly transportation alternatives should be evaluated (shuttle buses, bicycle lines, walking zones).
- Shuttle service can be provided from the center of Seferihisar to Sığacık by a low-speed light rail system. By this way, the noise will be reduced on the street which is one of the busiest stems and an alternative will be offered to sightseeing the town's natural and cultural values.
- The quality of public transportation should be improved.
- Transportation and traffic plans should be designed for safe and untidy traffic.
- Bicycle lines connecting both main stems and public transportation areas should be planned

Because of incorrect and inadequate implementations of urban planning, the traffic noise is at substantial magnitudes. One of the basic reasons of this is the inadequacy of Physical Development Planning Law on the designation of Transportation Master Plan and the integration of its results in line with the development plans. It will be an important step to eliminate legal deficiencies about urban planning in solving these problems.

Acknowledgments

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