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GIS-based mapping and assessment of noise pollution in Safranbolu, Karabuk, Turkey

Ertugrul Esmeray[1] · **Sercan Eren**[1]

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Abstract

In this study, it is aimed to determine and map the noise pollution levels in Safranbolu District Center, especially in the regions where motor vehicle and/or pedestrian traffic is intense. Forty-seven measurement points were selected for noise level measurements at the district center. Measurements were conducted at morning (8 a.m.–10 a.m.), lunchtime (12 p.m.–2 p.m.) and evening (6 p.m.–8 p.m.) hours of weekdays and weekends throughout the seasons of summer 2017 and winter 2018. The summer season weekdays noise level ranges from 41.3 to 71.2 dBA in the morning period, 40 to 71.2 dBA in the noon period and 40.6 to 73.1 dBA in the evening. The summer season weekend noise level ranges from 45.3 to 69.1 dBA in the morning period, 44.7 to 71.4 dBA in the noon period and 41.6 to 70.9 dBA in the evening. The result showed that the level of summer season weekday and weekend noise pollution in the morning, noon and evening is close to each other. In addition, the winter season weekdays noise level ranges from 32.3 to 68.5 dBA in the morning period, 30.8 to 73.3 dBA in the noon period and 37.4 to 72.9 dBA in the evening. The winter season weekend noise level ranges from 37.2 to 65.8 dBA in the morning period, 40 to 71.3 dBA in the noon period and 40.5 to 69.7 dBA in the evening. The result showed that the level of winter season weekdays and weekend noise pollution in the noon is generally higher than morning and evening. The obtained data are compared with the limit values specified in the Environmental Hazard Assessment and Management Regulation. The hazardous noise level, which is considered as the threshold for causing physiological problems on humans, was determined to be exceeded at many locations. This situation may cause significant negative consequences on human health, quality of life and tourism sector. Obtained data were processed, and noise pollution levels for the city of Safranbolu were mapped using a geostatistical analysis software. In total, 16 noise pollution maps were drawn for different situations (e.g., weekdays, weekend, daytime, noon, night, summer season, winter season, etc.). Obtained noise level results demonstrate that the overall quality of the acoustic environment in our study area was medium level, which means that exposure to these levels over a long period can affect human health and quality of life. Finally, the results of a survey conducted as a part of this study were given, and possible measures and suggestions to reduce these noise levels in the district down to the desired limit values were discussed.

Keywords Noise pollution · GIS-based mapping · Safranbolu

Extended author information available on the last page of the article

1 Introduction

Noise pollution is the whole of unwanted or harmful sounds that are in terms of health and quality of life, resulting from human activities. In recent years, excessive noise has also gained a different characteristic besides being a factor that causes discomfort. It is observed that when people are exposed to sound waves at high intensities for long periods of time, they lose their health (Kephalopoulos et al. 2014; Gupta et.al 2018; Kumar et al. 2018; Mehdi et al. 2018). Development of the transportation network, proliferation of motor vehicles, widespread mechanization and failures in protecting densely populated residential areas from noise due to unplanned rapid urbanization cause many problems in terms of public health. Noise pollution has been reported to be a major problem especially for those living in big cities (Bermúdez et al. 2019; Garg et al. 2017; Kalawapudi et al. 2020; Vladimir and Madalina 2019). Traffic, industry, construction, etc., in cities are the main source of noise pollution (Cueto et al. 2017; Kephalopoulos et al. 2014; Khodaei et al. 2009; Morel 2016; Morley et al. 2015; Yilmaz and Ozer 2005). Noise pollution has created a new working area for researchers, with the identification of noise pollution hazards on human health (Cueto et al. 2017; Majidi and Khosravi 2016). Many studies have shown that short- and long-term exposure to noise not only reduces human hearing, but also increases blood pressure, cardiovascular disease, anxiety and insomnia. Thus, noise exposure leads an increase in drug use and visits to hospitals (Farooqi et al. 2017). The noise caused by urban traffic can lead to increased heart diseases (Singh et al. 2018). Many academic studies showed that constant, variable and pulsed noise have negative effects on humans. The most harmful type of noise is the impact noise. The discomforts of the noise on humans are generally examined in four main groups: physical effects (ear problems, acoustic trauma); physiologically (blood pressure, circulatory, sleep disorder, respiration, acceleration, etc.); psychological effects (behavioral disorders, outburst of anger); and performance effects (inefficiency, concentration disturbance) (Garg et al. 2017; Singh et al. 2018; Farooqi 2017). Different kinds of problems that are caused by noise levels on humans are shown in Table 1.

Safranbolu is a city and a district center within the Karabük Province located in Western Black Sea Region of Turkey. Safranbolu is a popular tourist destination, and domestic and foreign visitors make a sizeable addition to the number of people present in the city, particularly, during the high season. A total of 68,440 people lives within the district borders (TUİK, 2019) and 315,842 tourists visited in the city in 2018 (Republic of Turkey Ministry of Culture and Tourism 2019). In addition, Safranbolu hosted about 76.000 domestic and foreign tourists with accommodation the first eight months of 2020 despite the COVID-19. In addition, Safranbolu hosted about 310,000 domestic and foreign tourists without accommodation on the same period despite COVID-19 (Ozler, 2020). The old town area of Safranbolu is in the list of UNESCO World Heritage sites since 1994 due

Table 1 Evaluation of noise levels (Anonymous, 1996)

Levels	Noise level dB(A)	Consequences
1.Level	30–65	Confusion, discomfort, anger, sleep, etc., disorders
2.Level	65–90	Physiological responses
3.Level	90–120	Increased physiological responses, headaches
4.Level	>120	Permanent damage to internal ear and balance deterioration
5.Level	>140	Serious brain destruction

to its well-preserved houses dating back to eighteenth and nineteenth century. Therefore, noise pollution is of great importance for the economy and human health in this region. Furthermore, four faculties and two vocational schools affiliated to Karabük University are located within the city borders and students of these institutions cause a significant increase during most of the year (except summer months) in local population. The students mostly are not registered as residents of the city and hence not counted in census data of the city. Accordingly, the noise population generation potential in Safranbolu City is anticipated to be greater than other cities with comparable sizes.

Although Safranbolu is a world cultural heritage city and attracts many tourists, the environmental issues of the city that are fundamentally associated to tourism have not been studied scientifically at a sufficient level. Future studies on this subject are being planned by Republic of Turkey Ministry of Environment and Urbanisation; however, there are not enough available scientific data on this subject in the literature for the district of Safranbolu (Karabük Prov. Direct. of Environ. and Forestry 2008, 2017). Due to unavailable environmental data, the decision-making processes related to dealing with environmental problems are very difficult and costly for local authorities. Also, in Safranbolu District, noise pollution is one of the issues where there is a need to raise public awareness. This study aims to collect noise pollution data that can be accessed by local authorities to create policies; to raise public awareness about the risks of noise pollution; and to contribute to scientific literature about possible measures to alleviate noise pollution.

2 Material and method

In the district of Safranbolu, 47 different points were determined to measure noise levels and to create a noise map, especially to identify noise levels in touristic areas. The coordinates of these points were determined according to geographic coordinate system with Garmin Etrex 10 GPS device. CEM DT-8852 brand Type 1 sound meter is used for noise measurements. The sound meter was calibrated with the CEM SC-05 before the noise measurements. The maximum sound pressure level of the noise meter is 130 dBA, and it is capable of measuring noise levels ranging from 30 to 130 dBA.

Satellite images to be used in GIS-based mapping processes must be of high resolution in terms of accuracy. Therefore, all the high-resolution satellite imagery used in this study was captured in 2018 through *Google Earth Software*. (Google Earth 2018).

The method chosen for the measurements was determined by examining many similar studies in scientific literature. When these studies are investigated, it is seen that similar measurement methods and measurement time periods are used (Farooqi et al. 2017; Karakus and Yıldız 2020; Kephalopoulos et al. 2014; Oguntunde et al. 2019; Rafael et al. 2015).

These 47 points were chosen to show the most accurate noise levels in the region. While determining the main measurement points in the study, the following criteria were taken into consideration.

- Creating proper placement density in different types of urban zones (most areas are “protected areas”; hence, measurement in residential areas was limited)
- Traffic density (main streets and roads in Safranbolu with heavy traffic)
- Touristic routes (pedestrian tourist traffic is an important source of noise)
- Shopping malls, bazaars and public markets that are popular among tourists and locals,
- University student dormitories,

- Cafes and restaurants,
- Establishments where live music is played.

First, the coordinates of those 47 measurement points were confirmed via GPS. Noise measurements were made in the summer of 2017 and in the winter of 2018. A total of 500 measurements were carried out throughout in this study. For each week, measurements were taken on 2 days in the weekdays of the week and on two days on the weekends of the week at each location. For each day, 3 separate measurements were recorded during morning, noon and evening hours. The measurements were made on a tripod at a height of 1.5 m from the ground level. Noise measurements were carried out within the borders of the City of Safranbolu at locations which are visited by tourists, between 07:00 and 09:00 in the morning, 12:00 and 14:00 at around the noon and 18.00 and 20:00 in the evening. For measuring accuracy, a minimum of 15-min-long measurement was made at each location. The measurement device automatically determined the maximum and minimum values within the measured values, excluding outliners. In this way, data points created due to erroneous signals and extreme high/low signals during data recording were not saved in the device memory. Using this built-in feature of the device, a higher validity level was achieved for the calculated average value of the 15-min measurements.

There are various novel methods that are available for mapping, such as statistical models (e.g., inverse distance weighting (IDW), local polynomial interpolation (LPI), radial basis function (RBF), ordinary kriging (OK), and empirical Bayes kriging (EBK)) and machine learning models using neural networks. Each method has its own advantages and disadvantages (İmamoglu et al. 2016; Bhunia et al. 2018; Arseni et al. 2019). RBF is one of the most important methods that are used to find an optimal shape parameter. With this method, data of any size can be easily converted to nonlinear data of another dimension. There are many fields of applications for the RBF method in numerical analysis and statistics, such as machine learning, data mining, digital solution of partial differential equations, GIS-based mapping, geodesy, meteorology, etc. (Adhikary and Dash 2017; Mongillo, 2011). RBF was preferred as the interpolation method in this study. In the RBF method, the surface must pass through each measured sample value. This method consists of five different basis functions: (1) thin-plate spline; (2) spline with tension; (3) completely regularized spline; (4) multiquadric function; and (5) inverse multiquadric function.

Each method has a different shape and a different interpolation surface. RBF methods are mostly used for calculating smooth surfaces from many data points (ESRI, 2020). RBF method can also provide excellent interpolants for high-dimensional data sets of poorly distributed data points. The most important advantages of RBF method over other methods are as follows. This method can give clearer results in a shorter time in numerical solutions of partial differential equations than others. It can be applied very easily to higher-dimensional functions about interpolation process (Curtarelli et al 2015; Rocha, 2009).

To prepare noise maps, a high-resolution satellite image of the city was captured from *Google Earth* software (Google Earth 2018). This satellite image was digitized in the ArcGIS program. The noise values fixed on the digitized measurement points were processed by RBF (radial basis function) interpolation method in Geostatistical Analyst Tools Module of ArcGIS v10.4.1 software. The obtained data were overlapped with the World Imagery map base, and a total of 16 noise pollution maps were created. Flowchart of noise pollution mapping method is presented in Fig. 1. The names of measured points and their coordinates can be seen in supplementary dataset file as Table S1. The satellite image,

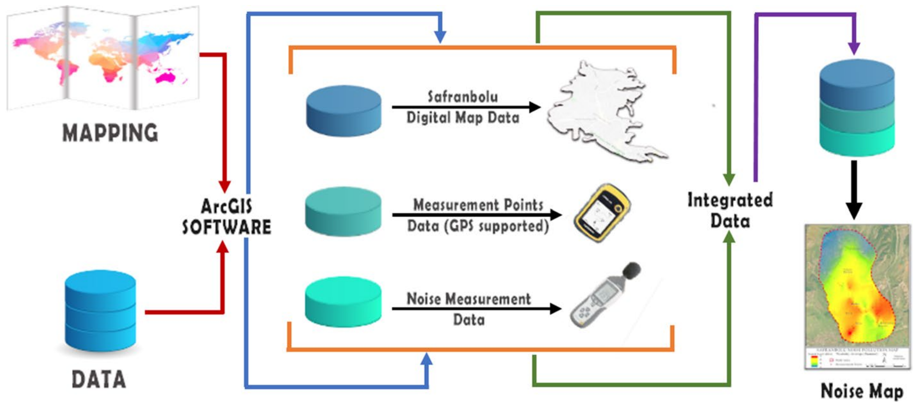

Fig. 1 Flowchart of noise pollution mapping method

which shows the measurement points, is shown in Fig. 2. Detailed map can be seen in Fig. S1 in supplementary dataset file.

The equivalent noise levels (Leq) were measured at 47 sample points in Safranbolu. The results that were obtained from measurements taken during weekday/weekend morning hours, lunch hours and evening hours in summer and winter seasons can be seen in Tables S3-S4-S5-S6 in the supplementary dataset file. The noise maps generated using the measured values in these tables are given in Fig. 5 for summer weekdays, in Fig. 6 for summer weekends and in Figs. 8 and 9 for the calculated average values, respectively. The data from winter season are delineated in Fig. 12 for winter weekdays, in Fig. 13 for winter weekends and in Figs. 15 and 16 for the average values. The abbreviations used in the tables can be seen in Table S2 in supplementary dataset file.

The distribution of the measurements which were made during weekdays at morning, lunchtime and evening hours throughout the summer season is shown in Fig. 3. It can be seen on the graph that the lowest values were at Point No. 30 (Çamtarla) and at 31 (Safranbolu City Forest) at noon and 34 (İnce Kaya Su Kemeri) at evening and that the highest noise measurements were obtained at the measuring point 12 (Terminal) during morning, afternoon and evening hours. At the measuring points No. 3, 9, 10, 11, 12, 14, 15, 16, 20, 21, 22, 37, 40, 42, 43, 45 and 46, values above 65 dBA (red line), which is the threshold value for starting to observe harmful physiological effects on humans (Table 1), were frequently observed. High stress levels, lack of concentration, hearing loss, tinnitus, sleep disturbances, hypertension and other harmful physiological reactions can be observed on the people that living near these locations with noise levels within the range of 65–90 dBA (Fig. 4).

The distribution of the measurements which were made during weekends at morning, lunchtime and evening hours throughout the summer season is shown in Fig. 4. The lowest values were recorded at 34 (İnce Kaya Su Kemeri) in the evening, while the highest noise levels were measured at 12 (Terminal) and at 20 (Eski Çarşı Meydan) at the lunchtimes. At the measuring points No. 11, 12, 14, 15, 16, 18, 19, 20, 21, 37, 40, 42, 43, 45 and 46, majority of the measured values were greater than 65 dBA (Figs. 5, 6).

Average noise distribution measurements for summer weekdays and weekends (L_{MNE} = average value of morning, noon and evening measurements) are shown in Fig. 7. The lowest average dBA values were estimated for 30 (Çamtarla) and 34 (İnce Kaya Su

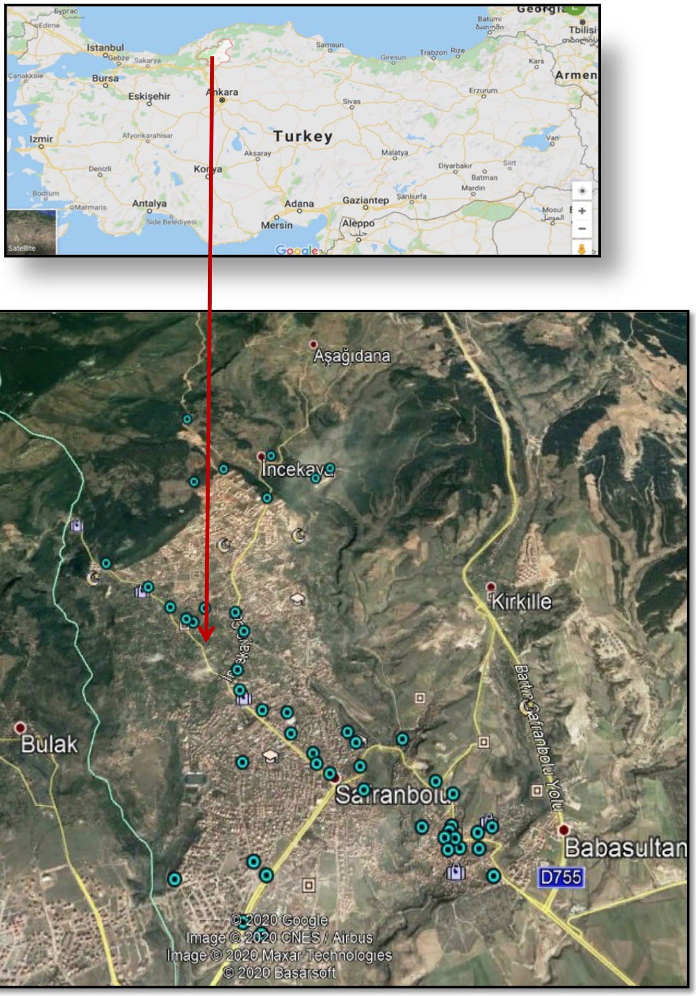

Fig. 2 Map and satellite image, which shows the measurement points (Google Earth 2018)

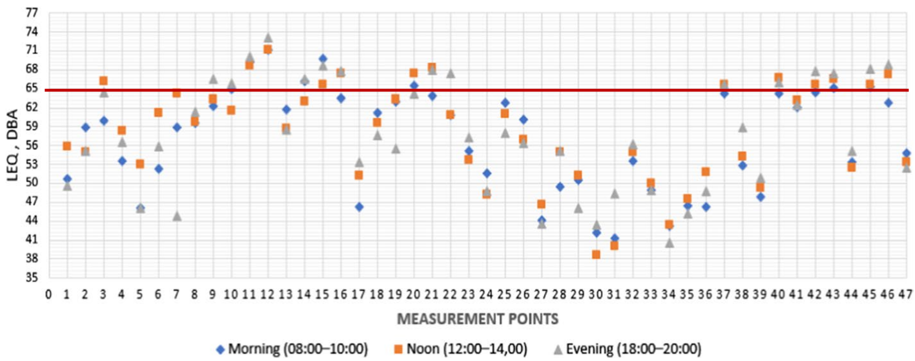

Fig. 3 Morning–noon–evening noise distribution in the summer season weekdays

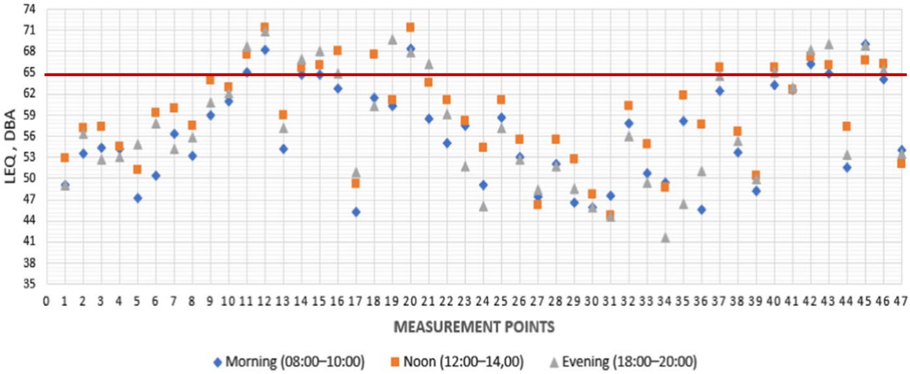

Fig. 4 Morning–noon–evening noise distribution in the summer season weekends

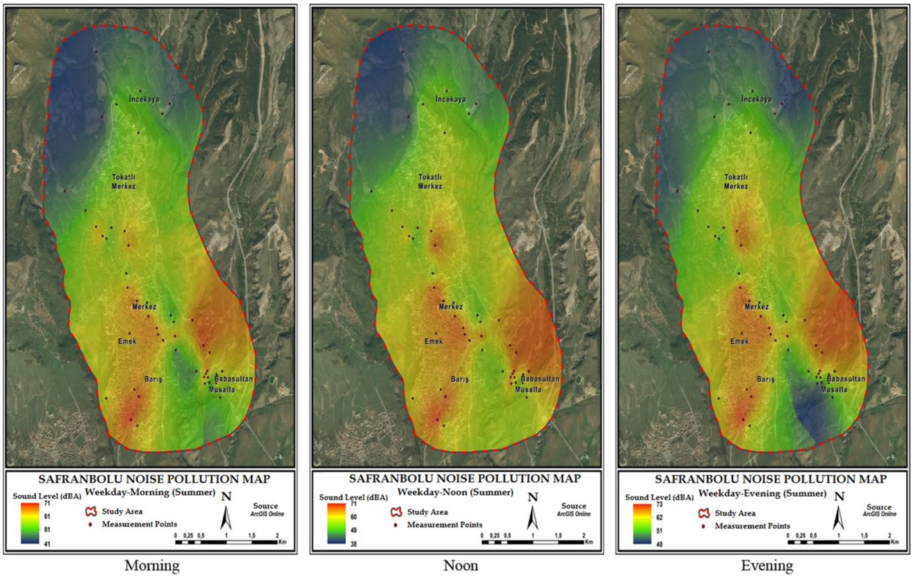

Fig. 5 Summer season weekdays morning–noon–evening noise measurement maps

Kemeri) on weekdays, while the highest average noise values were calculated for 12 (Terminal) on weekdays. At the measuring points No. 11, 12, 14, 15, 16, 19, 20, 21, 40, 42, 43, 45 and 46, calculated average values were above 65 dBA.

The noise pollution map, which is drawn using the calculated average noise values of the measurements taken during summer weekdays in Safranbolu, is given in Fig. 8. The noise pollution map, which is drawn using the calculated average noise values of the measurements taken during summer weekends in Safranbolu, is given in Fig. 9. On both maps the red–orange colored areas indicating higher noise levels on the map are the locations overlaps. The reason for the high level of noise in Merkez (Downtown of Safranbolu) and Emek Neighbourhoods is considered to be numerous restaurants, cafes, supermarkets and commercial other establishments located in these areas. The reason for the high level of noise in Barış Neighbourhood is the small industrial zone

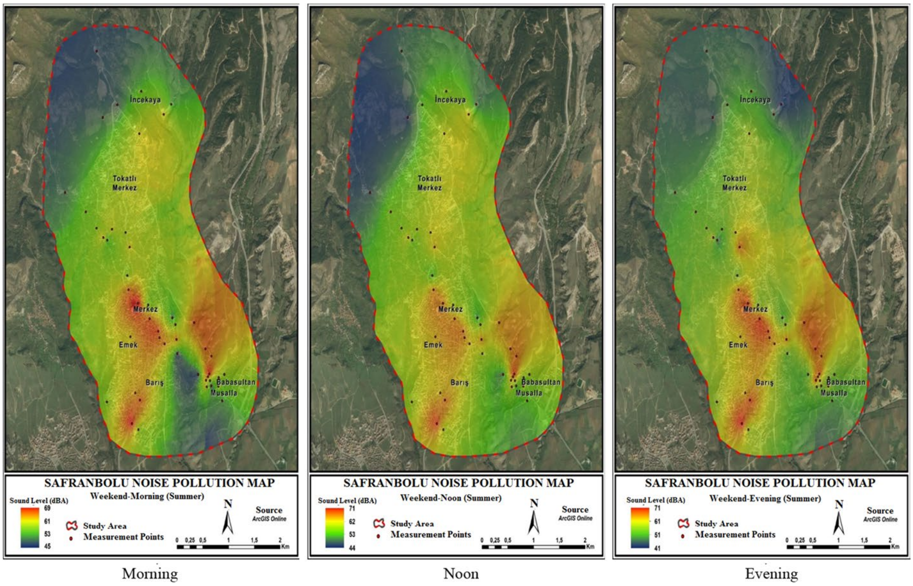

Fig. 6 Summer season weekend morning–noon–evening noise measurement maps

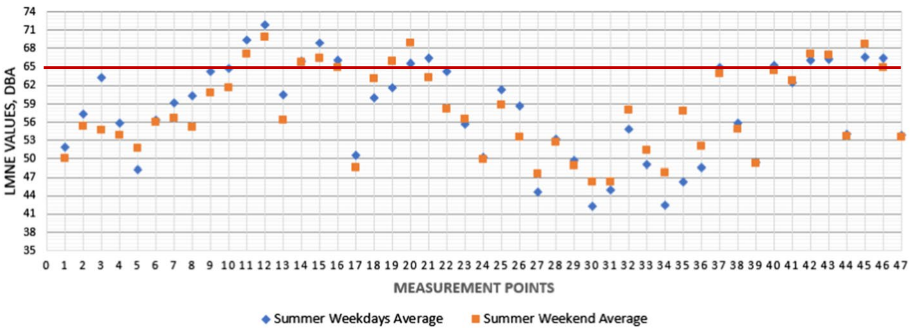

Fig. 7 Summer and weekend average noise distribution (L_{MNE})

containing various workshops, autoshops and small-scaled steel mills; the intercity bus terminal is also located in this area. The other red–orange colored patch of land (near the southeast corner of the mapped area) is where the Eski Çarşı (Old Town) and the connection point of Bartın highway is located. Old Town area is the main destinations for domestic and foreign visitors. Bartın highway is frequently used by people driving toward other popular touristic destinations, such as Amasra and İnkumu.

The distribution of the measurements which were made during weekdays at morning, lunchtime and evening hours throughout the winter season is shown in Fig. 10. The lowest values are recorded at 3 (Çamlıca Konak) at lunchtime and at 12 (Terminal), 22 (Cimbek Sokak) and 46 (Bağlar Saray) in the evening. The highest noise values were obtained at 3 (Terminal) at noon and evening hours. At the measuring points 3, 7, 9, 10, 11, 12, 16, 21, 22, 26, 37, 40, 42, 43, 45 and 46, measured values are above 65 dBA

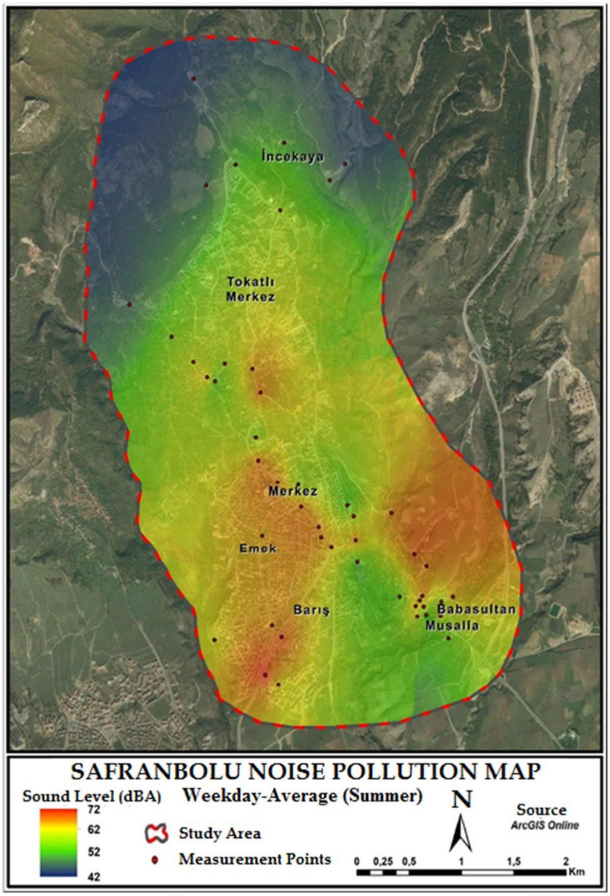

Fig. 8 Summer season weekdays average noise pollution map

threshold (Table 1). Physiological reactions can be observed on the people that living in these areas.

The distribution of the measurements which were made during weekends at morning, lunchtime and evening hours throughout the winter season is shown in Fig. 11. The lowest values were at 29 (Sarı Çiçek Villas) and 30 (Çamtarla) in the morning, while the highest value was obtained at 45 (Telekom) at lunchtime hours. At the measuring points 11, 12, 37, 40, 42, 43, 45 and 46, most of the recorded values were above 65 dBA (Figs. 12, 13).

The average distribution of the measurements (L_{MNE} = morning, noon and evening average noise distribution) which were made during weekends and weekdays in winter season is shown in Fig. 14. The lowest values were recorded at 30 (Çamtarla) on both weekdays and weekends. The highest noise values were recorded at 3 (Çamlıca Konak) on weekends. At the measuring points 3, 11, 12, 16, 21, 22, 37, 40, 42, 43, 45 and 46, most of the recorded values are above 65 dBA.

The noise pollution map obtained with the average noise values of the measurements taken during winter weekends in Safranbolu is given in Fig. 15. The noise pollution map obtained with the average noise values of the measurements taken during winter weekends in Safranbolu is given in Fig. 16. Comparing the results obtain during the winter and summer season, it is seen that areas with high noise levels mostly overlap. Only markedly

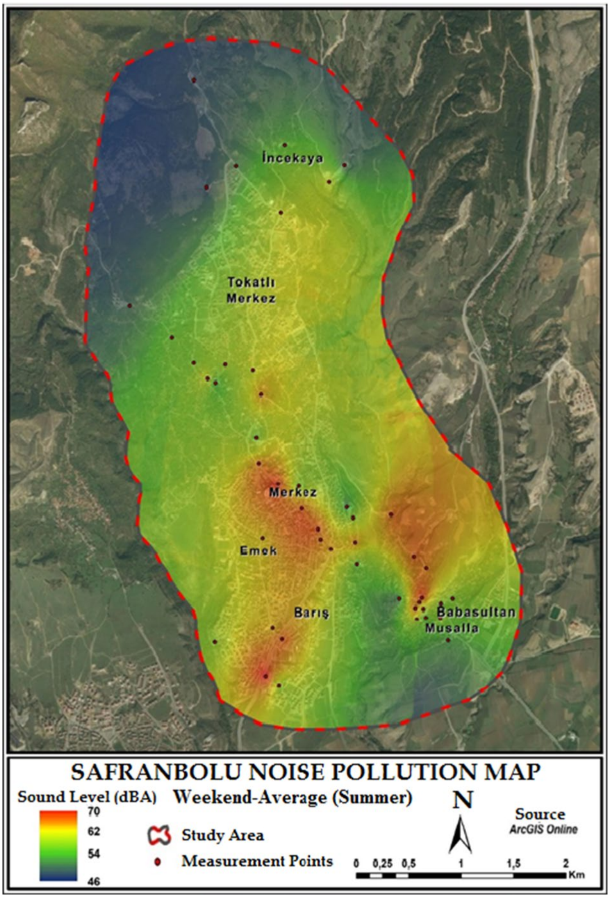

Fig. 9 Summer season weekends average noise pollution map

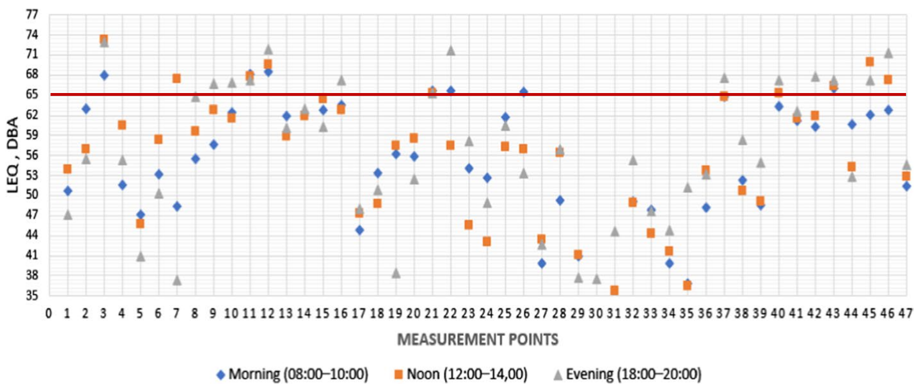

Fig. 10 Morning–noon–evening noise distribution in the winter season weekdays

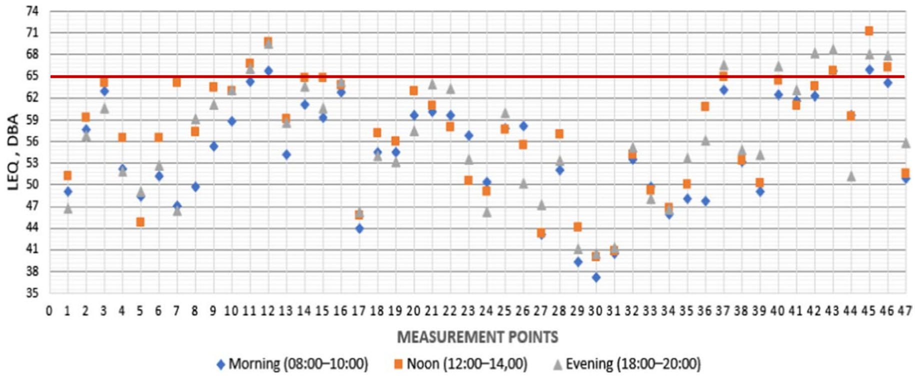

Fig. 11 Morning–noon–evening noise distribution in the winter season weekends

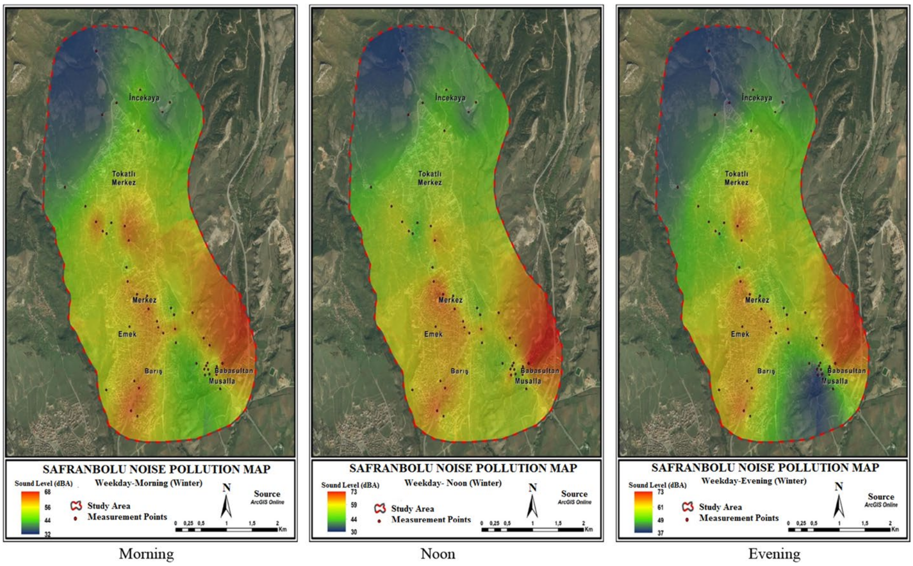

Fig. 12 Winter season weekday morning–noon–evening noise measurement maps

difference is that the noise level is slightly lower in Tokatlı and Incekaya villages because these two are less densely populated settlements and lower number of visitors during winter season.

3 Results

In the City of Safranbolu, 47 different measurement points have been chosen mostly near the main transportation routes and touristic areas, to determine and map the noise levels. The obtained results were compared to the limit values that are stated in Turkish Regulation on the Assessment and Management of Environmental Noise (Anonymous 2016).

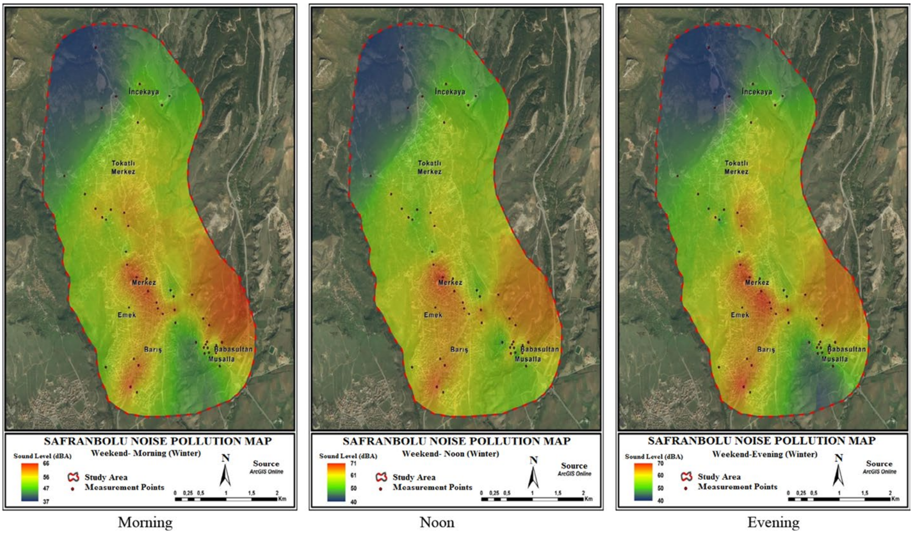

Fig. 13 Winter season weekends morning–noon–evening noise measurement maps

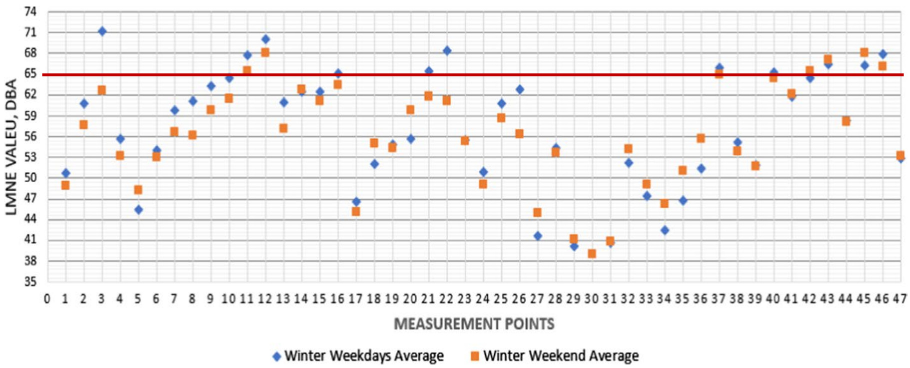

Fig. 14 Winter season, weekdays and weekend average noise distribution (L_{MNE})

Type of text The limit value of 65 dBA that is stated the "Regulation on the Assessment and Management of Environmental Noise" as a threshold for harmful health effect was exceeded at these points during the weekdays in winter: 71.20 dBA at Çamlıca Konak, 70.20 dBA at Terminal, 68.41 dBA at Cimbek Sokak, 67.99 dBA at Bağlar Saray, 67.82 dBA at Sanayi Girişi, 66.51 dBA at MADO, 66.23 dBA at Telekom, 65.96 dBA at Eski Çarşı Girişi, 65.46 dBA at Merhabası Yanında, 65.34 dBA at Japon Dostluk Anıtı and 65.04 at dBA Kalealtı İlkokulu.

The limit value was exceeded at these points during the weekends in winter: 68.16 dBA at Terminal, 68.03 dBA at Telekom, 67.04 dBA at MADO, 66.10 dBA at Bağlar Saray, 65.39 dBA at Sanayi Girişi and 65.37 dBA at Atamerkez.

The limit value was exceeded at these points during the weekdays in summer: 71.91 dBA at Terminal, 69.44 dBA at Sanayi Giriş, 68.89 dBA at Havuzlu Asmazlar Konağı, 66.53 dBA at Telekom, 66.47 dBA at Merhabası, 66.39 dBA at Bağlar Saray, 66.29 dBA

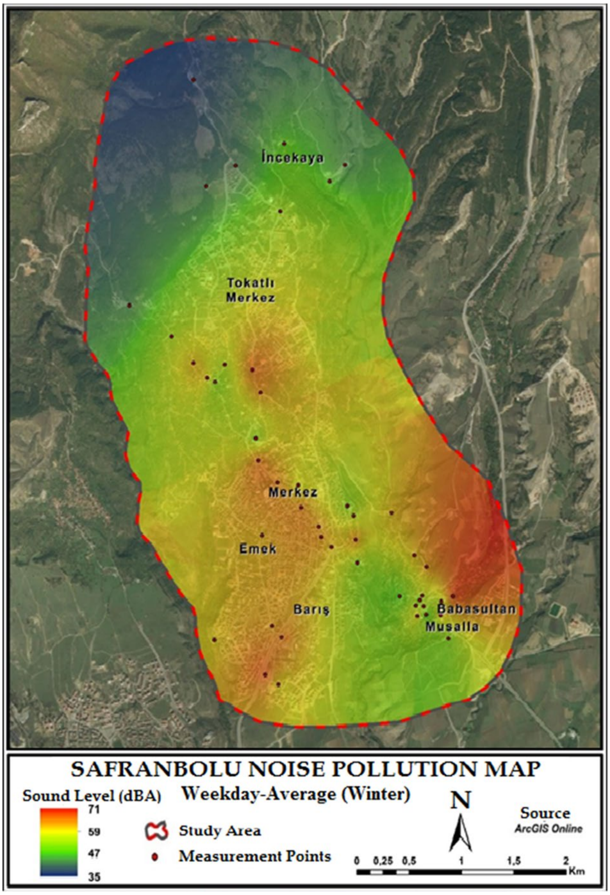

Fig. 15 Winter season weekdays average noise pollution map

at MADO, 66.13 dBA at Kalealtı İlkokulu, 66.02 dBA at Atamerkez AVM, 65.94 dBA at İsmet Paşa Mahallesi, 65.58 dBA at Eski Çarşı Meydan and 65.31 at dBA Japon Dostluk Anıtı.

The limit value was exceeded at these points during the weekends in summer: 69.89 dBA at Terminal, 68.97 dBA at Eski Çarşı Meydan, 68.76 dBA at Telekom, 67.15 dBA at Atamerkez AVM, 67.08 dBA at Sanayi Girişi, 66.89 dBA at MADO, 66.36 dBA at Havuzlu Asmazlar Konağı, 65.87 dBA at Arasta, 65.83 dBA at İsmet Paşa Mahallesi and 65.00 dBA at Bağlar Saray.

4 Discussion

Recently facilitated faculties and vocational schools that are affiliated units of Karabük University are in the center of the city. The literature on the subject suggests that the large number of students attending these schools may cause a spike in noise levels. In a similar study conducted on the campus of Suleyman Demirel University (Isparta, Turkey), 96 different points in the campus were measured and the average noise value was measured at 53.16 dBA. The highest measured value was 76.50 dBA, and the lowest measured value

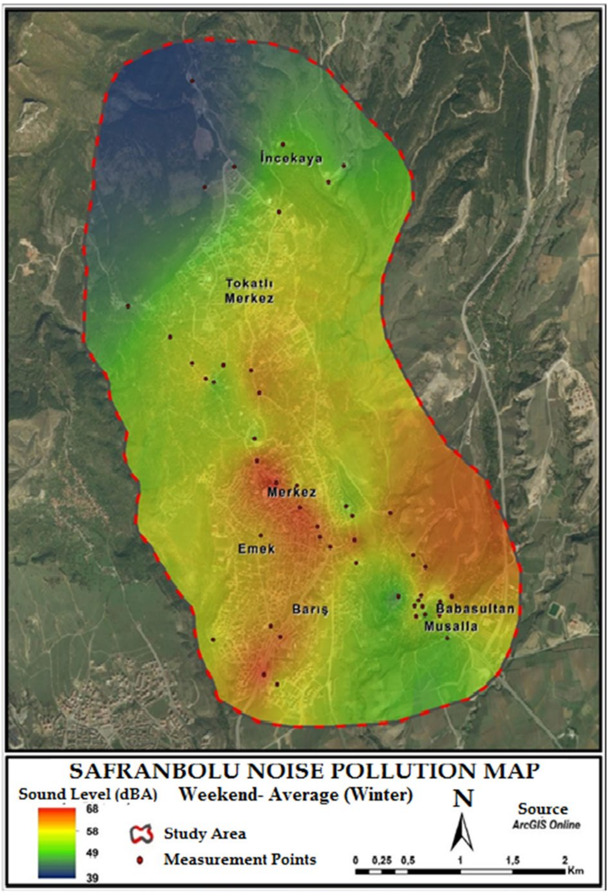

Fig. 16 Winter season weekend average noise pollution map

was 34.50 dBA. Processing the values obtained from the measurements, the noise maps of the campus were prepared in Morova et al. (2010). In another study, the measurement results from 7 different points in Çukurova University (Adana, Turkey) were between 70 and 75 dBA in the morning; between 45 and 50 dBA during evening hours; and between 30 and 35 dBA at night (Bicakci and Selek 2012). Also, in a different study carried out on Kanuni Campus of Karadeniz Technical University (Trabzon, Turkey), the noise levels were higher level than the limit values, and it was suggested to use a two-layered window system instead of single-layered system (Kavraz, 2015). Additionally, Karvaz suggested usage of multilayers and isolation layers on the wall sections.

All the historical streets in the Old Town of Safranbolu are cobblestone paved. This type of pavement causes 2–3 times higher noise levels compared to flat asphalt pavements (Bozkurt and Selek 2018). The Old Town area in Düzce Province, which is structured similar to Safranbolu Old Town, and the noise levels in the pedestrian areas were highest in the summer and the lowest in the winter season (Yerli, 2016). Observations support that motor vehicle traffic—although it is slower—in the Old Town creates a higher level of noise pollution compared to other parts of the town.

The usage of inappropriate exhaust silencer units in motor vehicles and negligence of necessary maintenance of the vehicles causes very high levels of noise in the district centers (Yilmaz and Ozer 2005; Cueto et al. 2017; Morley et al. 2015). Also, excessive honking on the roads increases the noise levels. The main reasons for these are the lack of a properly functioning traffic signaling system and traffic density in the urban areas (Bilgen, 2017; Sahin et al. 2016). The highest noise levels due to traffic were detected at the morning hours rather than at noon and evening hours (Aydın et al. 2005).

During this study, also a survey was conducted on noise pollution involving 500 people in order to determine the awareness level of the inhabitants and visitors about the issue. According to responses to the survey, 442 people considered noise as pollution; 38 people did not express noise as a pollution category; and 20 people did not comment about this issue. A total of 148 people reported that they have submitted complaints about the noise pollution, and 352 people did not act on this issue. Of the 148 people who filed a complaint, 90 of them made it over the telephone; 50 of them made face-to-face complaints; 20 of them made it through a written petition to the authorities; 8 of them made it by sending an e-mail to the authorities; 2 of them made it through the press; and 5 of them used other channels to convey their complaints.

In this study, the interpretation of the data implied that the highest contribution to the noise pollution in the City of Safranbolu is most likely generated by tourist population density. The students form a large portion of the local population during winter months, but most of the students are absent during summer. Despite students' absence, markedly higher noise levels were measured in the summer season compared to the winter season. This can be explained by a much greater number of visiting tourists compare to the absent students.

Most of the Safranbolu District Area is covered by "protected areas" under the protection of strict legislations prohibiting new construction, since the old town area is on the UNESCO World Heritage Center list. Accordingly, structural solutions to abate pollution from existing noise sources are not possible in most cases (such as installation of concrete and metal barriers). Instead, solutions to avoid noise should be natural and/or with minimum interference to the original architecture. These can be listed as: green barriers composed of plants and trees, sound insulation for important buildings, adopting contemporary urban planning techniques for creating new urban areas, noise reduction measures at the source of fixed noise sources and increasing awareness and sensibility of the local people.

Some case studies in the literature on natural solutions that may be suitable for environmental noise pollution control. Architectural landscape solutions can be considered to implement, such as forming noise barriers out of plants, green roofs, green walls etc. Plants can accomplish different forms of noise reduction through different parts in their structure. Sound can be reflected from or absorbed on the trunk, branches and leaves of the plants at different rates (Dimitrijević 2017). It was reported that the following many plants can be used as barriers to reduce noise level by ~ 5 dBA: *Hedera helix, Rubus fruticosus, Polygonum auberti, Parthenocissus quinquefolia*, *Viburnum rhytidophyllum, Acer pseudoplatanus, Betula verrucosa, Cornus alba, Corylus avellana, Crataegus monogyna Forsythia intermedia, Lonicera tatarica, Berberis thunbergia, Philadelphus coronarius, Populus tremula, Pyracantha coccinea, Ribes sp, Sambucus nigra, Sorbaria sorbifolia, Syringa vulgaris, Tilia cordata, Tilia platyphylla, Viburnum lantana, Cheamacyparis lawsoniana, Cotoneaster dammeri,Cupressus sempervirens leylandii, Cupressocyparis leylandii, Cupressus arizonica, Cupressus macrocarpa, Cupressus sempervirens cv. Glauca, Juniperus excelsa, Juniperus chinensis cv. Stricta, Juniperus horizontalis,Juniperus oxycedrus, Pinus mugo, Pinus mugo cv. Nigra, Pinus pinaster, Pinus radiata, Pinus silvestris and Thuja orientalis, Photinia fraseri*, *Photinia serru- lata*, *Spirea vanhouetti Nerium indicum*, O*ligostachyum lubricum*, *Cedrus deodara*, *Viburnum odoratissimum*. (Erdogan and

Yazgan 2007; Ozer et al. 2008; Fan et al. 2010; Onder and Kocbeker 2012; Ropus et al. 2013; Ferrini et al. 2020; Paul et al. 2020).

The measures that can be taken by the local government are as follows (Environmental Noise Directive 2002; Maffei and Masullo 2014; Mahler and Bohli 2015; Penton 2016; Dimitrijević 2017; Jacyna et al. 2017; Jena et al. 2018; Boren 2019; Ferrini et al. 2020; EU-European Commission 2020a, b):

- Ensuring that the new buildings to be built in the region comply with the "Protection of Buildings Against Noise" regulation.
- Replacing traditional asphalt pavement with more efficient alternative options (this is more effective than other options in reducing traffic noise),
- Increasing the number of noise-protected pedestrian zones by restricting vehicle traffic and unloading at certain times of the day,
- Increasing cycling paths,
- Regular maintenance of municipal vehicles,
- In the long term, preferring procurement of hybrid or electric vehicles for municipal services,
- In the long term, switching to hybrid or electric public transport vehicles.
- Applying green solutions to prevent environmental noise pollution (such as green living walls, green roofs, natural barriers made from suitable trees, plants, ivy and bush types)
- Applying natural solutions involving use of eco-friendly insolation materials to prevent environmental noise pollution (such as jute, sheep wool, rice paddy, sugar cane, coconut fibers, husk and rice straw types)
- Use of soundproof construction materials,
- Noise isolation certification for residential and commercial buildings.
- Activities to create environmental noise awareness in the society

Environmental noise pollution management and control can be successfully carried out by considering the above-mentioned measures and recommendations. Otherwise, environmental noise will emerge as a major problem in regions with rapidly growing populations and tourism potential, like Safranbolu.

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Authors and Affiliations

Ertugrul Esmeray[1] · Sercan Eren[1]

✉ Ertugrul Esmeray
eesmeray@karabuk.edu.tr

1 Civil & Environmental Engineering Department, Engineering Faculty, Karabuk University, Room: 441 Campus, Karabuk, Turkey