Urban land use effect analysis on the level of noise pollution using satellite and GIS technologies: A case study in Tehran city

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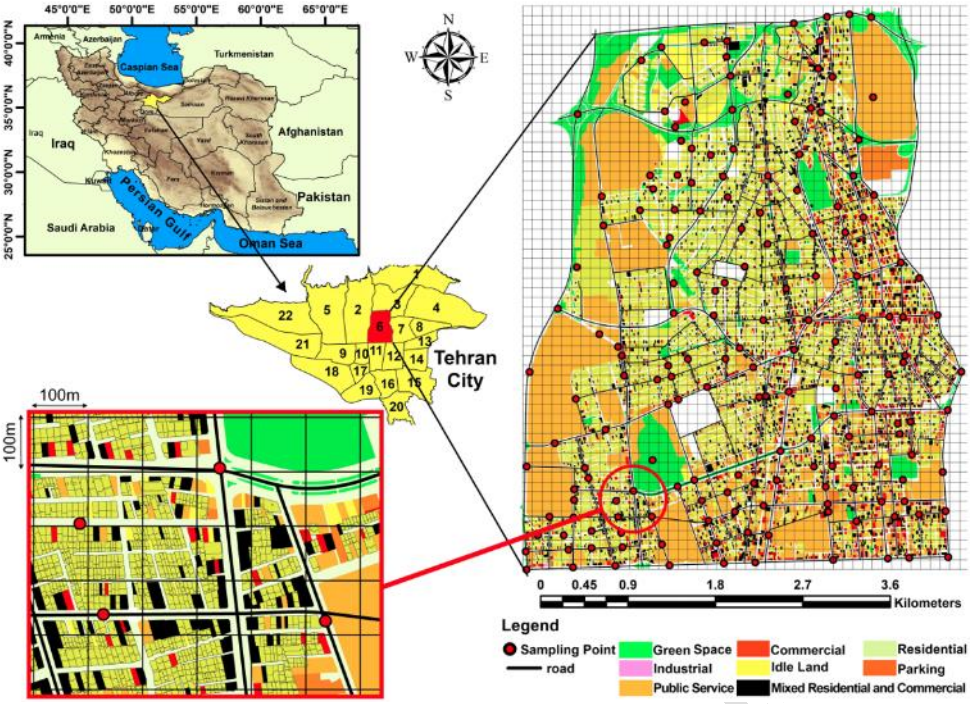
ABSTRACT

We utilized satellite and GIS technologies to address the relationship between urban land uses and Noise Pollution (NP) in one of the most crowded regions of Tehran city. L_{eq} was determined in 170 stations of the studied area and an acoustic map was created. Moreover, using satellite remote sensing data and a land use map, the density map for nine types of the most important urban land use was provided and the relationship between different land use densities and NP was investigated. We found that the investigated region was highly polluted and the NP level was higher in the morning (76.29±5.61 dB[A]) and afternoon (76.46±4.88 dB[A]) in comparison to the noon period. Furthermore, the prepared acoustic map revealed that in the east and southwest of the studied area, the NP was highest and lowest, respectively. Also, cultural (73.48±4.7 dB[A]) and parking (79.02±4.3 dB[A]) areas had the lowest and highest levels of L_{eq}. Also, the high density of road, commercial, industrial, mixed commercial and residential and parking land uses had a direct significant relationship with L_{eq} and this relation was inverse for green space. It was concluded that land use variations significantly affect the NP levels and it can be utilized to predict and manage the NP in different cities.

Keywords: noise pollution, acoustic mapping, land use, Tehran, Iran

GRAPHICAL ABSTRACT



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Mixed Residential and Commercial
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Parking

1. Introduction

Nowadays, around 54% of the population lives in cities, and by 2050, the population is expected to reach 66% (Margaritis & Kang, 2017). This ever-increasing rate of population leads to a significant increase in environmental problems. Among the different environmental problems, noise is one of the most important pollutions (Hamed & Effat, 2007) and it is considered a growing problem (Aparicio-Ramon, et al., 1993; Hunashal & Patil, 2012; Lercher, 1996; Williams & McCrae, 1995) that considerably affects the life quality in the big cities (Abbaspour, Karimi, Nassiri, Monazzam, & Taghavi, 2015). Noise pollution (NP) is an unwanted sound (Barrigón Morillas, Gómez Escobar, Méndez Sierra, Vílchez Gómez, & Trujillo Carmona, 2002; Kisku, et al., 2006). The monitoring and management of NP are different from other urban pollutants due to its source features as well as its release form. People pay less attention to NP compared to other problems such as air pollution and water pollution due to its invisibility, short decay time and difficulty to associate cause with effect (Alam, 2011; Jamrah, Al-Omari, & Sharabi, 2006). NP has harmful effects on humans (Abbaspour, et al., 2015; Hunashal & Patil, 2012; Lagonigro, Martori, & Apparicio, 2018). According to the reports of the world health organization (WHO), after air pollution, noise is the biggest cause of health problems around the world (Barrigón Morillas, et al., 2002). It can affect the human health by its physical (hearing defects), physiological (increased blood pressure), psychological (insomnia, irritability, and stress), and functional (reduction of productivity and misunderstanding what is heard) aspects (Abbaspour, et al., 2015; Alesheikh & Omidvari, 2010; Hunashal & Patil, 2012; Langdon, 1976; Ouis, 2001), but the most important adverse effect of exposure to high levels of noise is deafness, which initially is temporary but can be a permanent illness over a long period (Alam, 2011). Monitoring the different noise sources in an urban area, preparing an acoustic map, and determining the areas with high NP are of central importance because it is possible to use management and engineering measures to control the noise level and its risks (Ryu, Park, Chun, & Chang, 2017; Xie, Liu, & Chen, 2011).

In creating acoustic maps, in addition to the noise level, effective factors such as Urban Land Use (ULU) distribution should be considered (Steele, 2001). In an urban area, the type of ULU plays an important role in the NP rate because in regions with different ULUs, different activities are conducted that lead to different noise levels. Therefore, the ULU parameter can directly be used in predicting the NP and it can help the urban managers to have more accurate planning for controlling the NP. Some studies have been conducted to survey the level of noise pollution in some urban land use so far, for example, Doygun and Gurun (Doygun & Kusat Gurun, 2008), Hunashal and Patil (Hunashal & Patil, 2012), Zannin et al. (Zannin, Diniz, & Barbosa, 2002), Morillas et al. (Barrigón Morillas, et al., 2002) have investigated the NP in some ULUs, such as residential, commercial, industrial, recreational, educational, and road areas. However, the role of this type of ULU and other ULUs, such as green space, parking, idle lands, and land use for public service in NP has not been fully evaluated, and it is necessary to perform detailed studies to predict more accurate the areas which are exposed to NP.

Tehran is one of the highly populated cities in the world, it burdened with various environmental pressures such as NP. So far, few studies have been conducted to investigate the NP in Tehran. One of the aims of the present research is to prepare the acoustic map of the most populous and busiest districts of Tehran in different hours of the day using GIS and make a proper framework to adopt sound reduction policies and tools. Another aim is the evaluation of the ULU effect on the NP rate.

2. Materials and methods

2.1. Study area

Tehran has an extend of 574 km^2 inhabited by 14 million people according to the last census that conducted in 2017 and it is the 25th most populous city in the world. The height of the city at its highest point is about 2000 meters above the sea level in the north and the lowest point is 1050 meters above the sea level in the south. The climate in northern parts of this city is cold and dry and the southern regions are warm and dry. In the last 40 years, Tehran has had huge economic and industrial growth.

Tehran is divided into 22 districts (Fig.1). In this research, district 6 was selected to evaluate because based on the noise monitoring stations, it had the maximum NP among the different districts in Tehran city. The population of the study area was determined to be 384,251. District 6 has a dense population and traffic during the day and the density of buildings, residential, and commercial apartments is considerable. In this area, trucks do not allow traveling during the day and only city vehicles and buses can travel. BRT (Bus Rapid Transit) lines that use vehicles with a diesel engine (with a high level of sound pressure) are present in most of the area. Motorcycle traffic is also higher than in other areas.

2.2. Noise evaluation and measurement

170 temporary sampling stations were randomly selected in the study area in a way that took into consideration all types of land use, i.e., roads, industrial, commercial, mixed commercial and residential, residential, idle lands, parking, and public service land uses. Fig.1 shows the distribution of the sampling stations spread through the study area. All measurements were carried out during the winter in 2018 (temperature -3 to 18 degrees celsius). The latitude and longitude of each station were determined by the GPS (MAGELLAN, model -315).

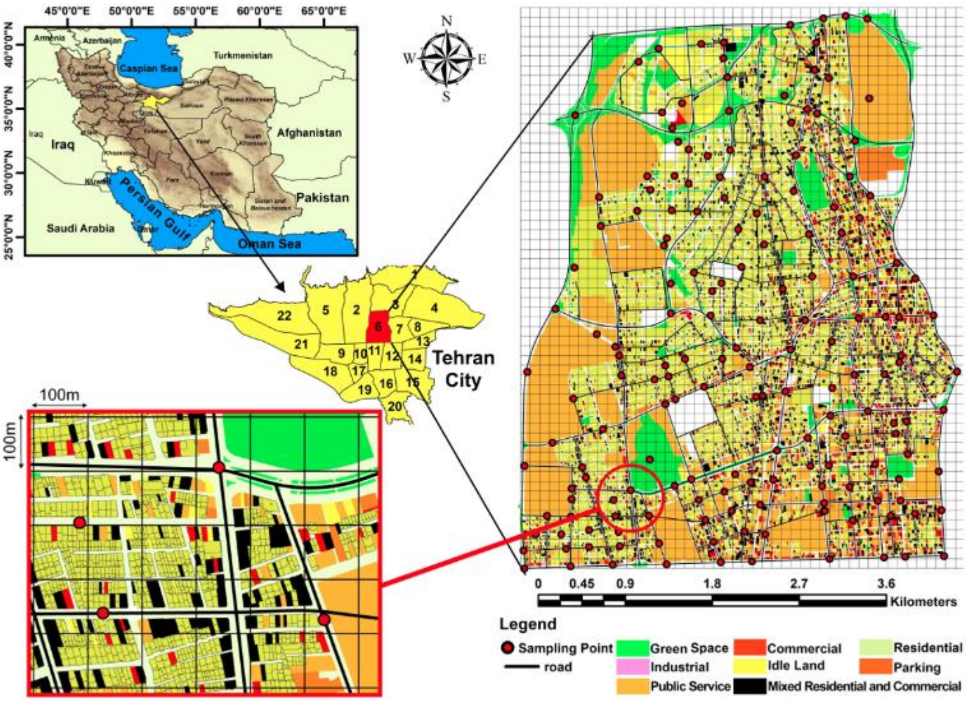

Figure 1. Noise measurement stations and urban land use in district 6 of Tehran

In accordance with ISO1996-2, at the sampling stations, A-weighted continuous equivalent sound level (L_{eq}) was measured using Cacella Cel sound level meter (model-CEL 268 Environmental Noise Meter, England). The sound level meter was kept at a height of 1.5 meters above ground level and 3 meters away from any reflector surface. For each station, measurements were performed continuously for 1 day, at intervals (morning-noon-afternoon) during weekdays (with 12 hours of follow-up per day). The program selected during the day is as follows: morning from 7 a.m. to 11 a.m., noon from 11 a.m. to 3 p.m., afternoon from 3 p.m. to 7 p.m. For each time interval, the sound level was recorded every 5 minutes (for example, 12 readings per hour). Data were evaluated using the equivalent continuous sound pressure level (L_{eq}) (Tsai, Lin, & Chen, 2009; Xie, et al., 2011).

2.3. Acoustic mapping and the relationship between land use and noise pollution

To prepare the acoustic map, the ULU map related to district 6 of Tehran was prepared (Fig.1). In addition, the location of the sampling stations was imported in ArcGIS software as a layer and the L_{eq} values were determined for each station. Then, an acoustic map for the morning, noon, and the afternoon was separately provided using the kriging interpolation method. Also, the areas with the highest and lowest NP rate (with 90, 95, and 99% confidence intervals) were determined on the map by hot spot analysis. To investigate the relationship between ULU type and noise level, roads, industrial, commercial, mixed commercial and residential, residential, idle lands, parking, and public service land uses were extracted separately from land use map and saved in separate layers. Furthermore, satellite images were employed to prepare the green land map of the area. For this purpose, the Normalized Differential Vegetation Index (NDVI) images were utilized. NDVI images prepare a map of biomass from the study area. The chlorophyll absorption in red band and relatively high reflectance of vegetation in the Near-Infrared band (NIR) were used in order to calculate NDVI. To classify the NDVI images, the maximum likelihood classification method was used and then the accuracy of the prepared map was approved by comparing it with aerial images. Afterward, the prepared green land map was saved as a separate ULU type layer. The density of each mentioned ULU types were prepared using the kernel-density method. Then, the study area was divided into 2240 cells (100×100m cells) (Fig.1) and the mean density of each ULU types were calculated for each cell. In terms of vegetation density, the vegetation area was calculated in each cell (10000 m^2). In the case of roads, the total length of the paths in each of the designated cells was calculated. The densities obtained for each ULU type were compared with the prepared NP map of the studied area, thus, the effect of ULU on the level of NP was investigated. Kruskal-Wallis test was used to determine the significance of L_{eq} differences in different periods and the Signed rank-sum test was utilized for comparison of L_{eq} values with the standards. Besides, the spatial analysis was performed using ArcGIS v10.1 software and to statistical analysis of collected data, SPSS v15 and Excel 2010 (Microsoft Office Package) were used.

3. Results and Discussion

3.1. Temporal and spatial assessment

Studies about the Tehran environmental NP are rare. Collection and analysis of NP data are one of the main elements of the assessment and management of urban environmental noise (Jamrah, et al., 2006). Therefore, in the present research, the noise level in 170 stations was measured in morning, noon, and afternoon to evaluate the NP in one of the busiest areas in Tehran. The results are presented in Table 1. According to Table 1, in the morning, the mean L_{eq} was 76.29 dB[A]. Moreover, in noon and afternoon, the mean L_{eq} respectively were 75.75 and 76.46 dB[A]. The NP higher than 55 dB[A] can cause aggressive behavior and sleeping disorder (Berglund, et al., 1999). Also, long-time exposure to 65 dB[A] might lead to hypertension; and stress levels, heart rates, and potential hearing loss would be increased at 75 dB[A] (Doygun & Kusat Gurun, 2008). Noise exposure consequences might be worse for particular subgroups such as children, elderlies, and lower socioeconomic groups (Lagonigro, et al., 2018). The Iranian Department of Environment considers 55, 60, 70, and 75 dB[A] as the standard NP level for residential, commercial-residential, commercial, residential-industrial, and industrial area, respectively (Monazzam, et al., 2015). Therefore, the results demonstrate that the study area is severely noise polluted. Other studies that were conducted in Yazd province in Iran and district 14 of Tehran reported that the mean L_{eq} was 74.41 (70.9-80.7) and 72 (62.3-84.2) dB[A], respectively. Morillas et al. (Barrigón Morillas, et al., 2002) performed a study in a small and non-industrial city in Spain and reported that in the 90 % of noise measurements, L_{eq} has recorded higher than 65 dB[A]. Deniz Çolakkadıog˘ and Muzaffer Yücel conducted a study in Adana city center in Turkey and showed that in 63 percent of evaluated lands, L_{eq} value is higher than 68 dB[A] during the day (Çolakkadıoğlu & Yücel, 2017). Fiedler and Zannin found that in the 73 percent of the noise measurement stations in the Curitiba in southern Brazil, the noise level was higher than 65 dB[A] (Fiedler & Zannin, 2015). In the present research, the studied area is located in the inner city and the existence of many commercial, industrial and official centers, as well as a high density roads and highways, explain this high NP level.

The results of the Kruskal-Wallis test indicated that no significant difference was observed between L_{eq} values in the morning, noon, and afternoon (P-value>0.05), but according to Table 1, the mean of L_{eq} in noon was lower than that of morning and afternoon. Since in the studied area, there are many educational, commercial, and public service centers, in the morning, many people travel to these centers and in the afternoon, they come back home. Also, in the afternoon, people come to shopping centers and recreation places, which lead to increasing L_{eq} values in the morning and afternoon. Several studies have shown a similar pattern. For instance, Hakan Doygun and Derya Kuşat Gurun found that the minimum and maximum NP occurred during the mid-day and evening hours in Turkey (Doygun & Kusat Gurun, 2008). In another study, Hunashal and Patil performed a study in Kolhapur city and reported the maximum L_{eq} in industrial and commercial regions in the afternoon (4-5 p.m.) (Hunashal & Patil, 2012). Moreover, in Karachi city in Pakistan, such as our findings, the noise level in the morning and afternoon was higher than that in the noon and mean L_{eq} measured in the morning, noon, and afternoon respectively were reported 79, 73, and 80 dB[A] (Mehdi, Kim, Seong, & Arsalan, 2011).

Table 1. L_{eq} values measured in the morning, noon, and afternoon

Period	L_{eq} dB[A]					Percentiles		
	mean	**95% CI for mean**	**S.D**	**median**	**lowest-highest**	**10**	**75**	**90**
Morning	76.29	75.44 to 77.14	5.61	77	62.2-87.2	67.85	80	82.65
Noon	75.75	74.95 to 76.56	5.31	76.75	60.5-86	68.3	79.2	82
Afternon	76.46	75.72 to 77.2	4.88	77	62.5-86.5	69.5	80	83
Overall	76.17	75.71-76.63	5.28	77	60.5-87.2	68.8	80	82.3

Acoustic mapping is an important task to develop methods for controlling NP (Jamrah, et al., 2006). Therefore, we aimed at preparing an acoustic map from the studied area. For this purpose, after determining L_{eq} of each station, an acoustic map of each interval was plotted using a kriging interpolation method (Fig.2). According to Fig.2, in all the studied intervals (morning, noon, and afternoon) the L_{eq} values in the eastern regions of the surveyed area were the highest so that in all studied time intervals, L_{eq} values were determined between 81 to 86 dB[A]. The acoustic map of the studied area demonstrated that the NP level in the center and the west side of the area was medium while it was minimum in the southwest of the area. Finally, the L_{eq} value was lower than 72 dB[A] for all studied time intervals. The prepared map showed that in the morning, NP expansion rate in the east of the studied area was higher than noon and afternoon; in contrast, in the afternoon, the area with a L_{eq} higher than 81 dB[A] was denser and smaller, while the areas with NP of 69-72 dB[A]and 78-79 dB[A]were more expanded (Fig.2).

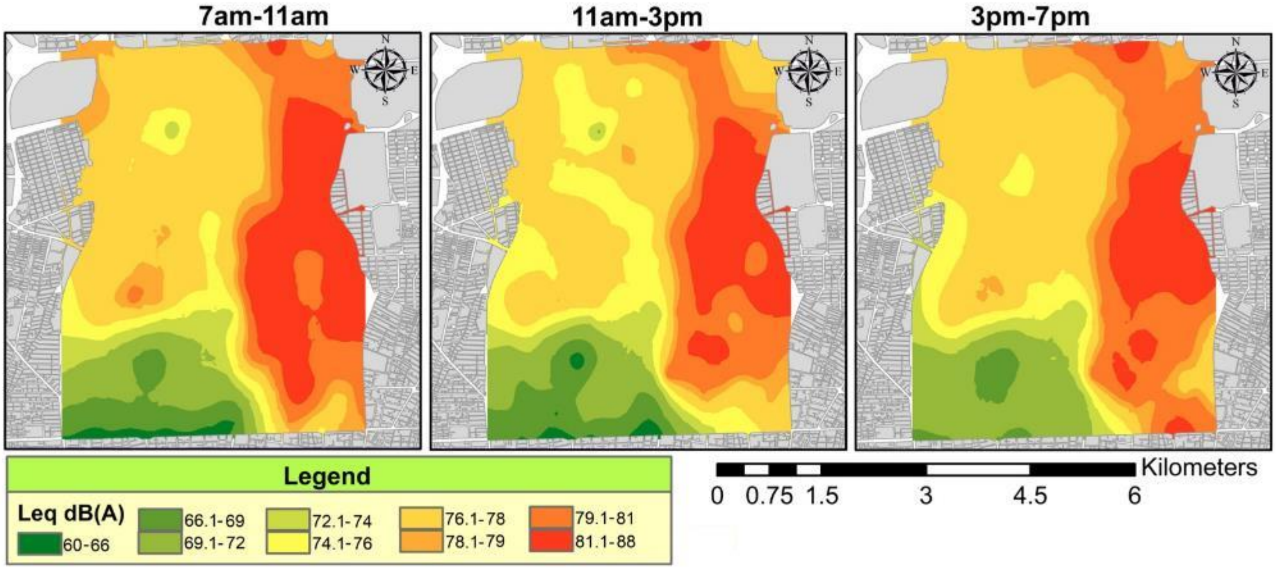

Figure 2. The acoustic map of the studied area in the morning, noon, and afternoon

Furthermore, in all three investigated intervals, the areas with L_{eq} of 74-79 dB[A] (areas with yellow and light orange colors) almost cover all the north, center and west of the studied area. Only in the morning, small parts in the center and northwest have L_{eq} in the range of 78-81 dB[A]. In order to confirm the most polluted parts of the studied area, Hot spot analysis was performed on all data collected in the morning, noon, and afternoon overlay, and the results are depicted in Fig.3. According to Fig.3, the most polluted parts are located in the east of the studied area; hence, Tehran municipality managers should put the polluted points on the priority of NP control plans. Besides, the southern and southeastern regions of the studied area had the lowest NP compared to the rest of the studied points, although the values obtained for this area also exceeded the standards (Fig.2).

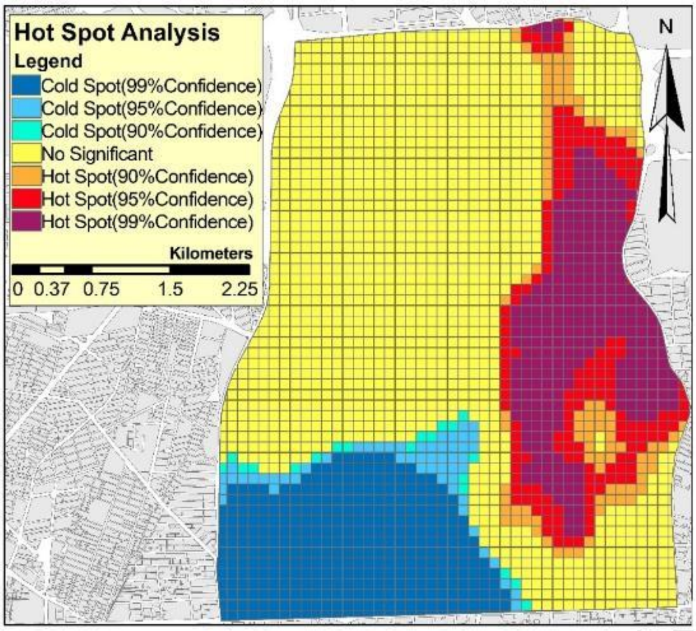

Figure 3. Hot spot analysis of noise pollution in the studied area

The mean, minimum, and maximum L_{eq} values were determined in regions with different ULUs using the prepared acoustic map; and the obtained results are presented in Table 2. The results showed that the areas with cultural and parking use had the lowest (73.48 ± 4.7dB[A]) and the highest (79.02 ± 4.3dB[A]) NP, respectively. There are usually dense green spaces around cultural areas such as museums, theaters, mosques, and libraries, hence a lower L_{eq} is expected in such places. On the other hand, areas similar to the parking check point have the highest L_{eq} among the other ULUs. It can be explained that this place usually is located in the busiest part of the cities and in most of the time the traffic of cars is heavy in such areas. According to Table 2, none of the ULUs could meet the standards of the Iranian Department of Environment. Many other studies that have been carried out in the cities of other countries have determined L_{eq} values for different ULUs, for example, in Kahramanmaraş city, the L_{eq} values respectively were 62 and 68 dB[A] in the residential and industrial regions (Doygun & Kusat Gurun, 2008). In another study in India, in the commercial and industrial area, L_{eq} was 72.25 and 65.3 dB[A], respectively (Hunashal & Patil, 2012). Also, Kisku et al. performed a study in Lucknow (India) and reported that L_{eq} average in residential and commercial areas was 64.06 and 74.48 dB[A], respectively (Kisku, et al., 2006). In all of the studies, L_{eq} was significantly lower than the values obtained in this study. Among 2240 studied cells (Fig.1) 90 percent of them had to mean L_{eq} over 71 dB, which confirmed a high NP in the studied area. As seen in Table 2, the L_{eq} value of different ULUs are as follows: Cultural< Health Centers< Educational < Idle Land< Residential< Public Service < Mixed Residential & Commercial< administrative< Industrial< Commercial< Parking.

Table 2. The mean value, minimum, and maximum L_{eq} in different land uses

3.2. The relationship between land use and noise pollution

Land Use Type	Count	Area (m^2)	Percentage in total area (%)	Mean (dB[A])	Min-Max (dB[A])
Cultural	53	114131.25	0.76	73.48±4.7	64.41-83.04
Health Centers	199	482399.04	3.24	74.01±4.6	67.24-83.27
Educational	532	2293055.77	15.2	75.50±3.1	66.12-83.47
Idle Land	2109	855005.41	5.75	76.99±3	66.42-83.52
Residential	49566	6130102.42	40.1	77.01±3.7	66.47-83.42
Public Service	838	429961.49	2.91	77.34±4.46	66.31-83.53
Mixed Residential & Commercial	10209	1472158.11	9.9	77.35±4.4	66.22-83.49
administrative	1559	1559277.92	10.2	77.76±3.8	66.26-84.63
Industrial	383	55394.22	0.37	78.03±4.5	66.52-83.17
Commercial	4281	693686.59	4.66	78.26±4.3	66.28-83.63
Parking	499	302795.56	2.03	79.02±4.3	66.35-83.27

ULU composition can deeply affect the environmental noise, so the combination of ULU in a city can be used to predict and manage the NP. As mentioned, in order to evaluate the association between the ULU and L_{eq}, authors selected the most important ULUs that might have a relationship with L_{eq}; they included commercial, industrial, roads, idle lands, residential, mixed commercial and residential, green land, public service, and parking spots. We determined the density (in km^2) of each ULU in separate layers (except roads and green land, in which length and area of each cell were calculated) (Fig.4). In addition, hot spot analysis was used to determine statistically the areas with the highest and lowest density and the results are illustrated in Fig.5. Moreover, in order to further investigate about the effect of ULU on the L_{eq} level, the L_{eq} values in the hot spot areas and the cold spot areas were separately compared in each ULUs (Fig.6). To determine the significance in the noise level difference between two areas with hot and cold spots, the Mann-Whitney test was employed and Spearman's coefficient of rank correlation (rho) was used to evaluate the relationship between the ULU and noise level.

As seen in Fig.4, in the east of the studied area, the density of the number of commercial land use is more than other parts, so that in some parts of eastern areas, the density reaches 756 to 1087 per Km^2. Also, Fig.5 confirms that the eastern region with 99% confidence interval has the most areas with a high density of commercial use and according to Fig.3, the eastern region is located in a high NP zone that is probably due to the high number of commuters as well as the high traffic congestion in commercial areas. Fig.6 illustrates that median of the noise level in the areas with a high density of commercial use (Hot spot areas) is 80.55 dB[A], which is significantly higher compared to Cold spot area (76.65 dB[A]); Mann-Whitney test determined that this difference is significant (U=88486, P<0.0001). Besides, it is revealed that an increase in the density of commercial land use leads to increasing NP (r=0.38, P<0.0001).

Also, the density pattern of the industrial areas completely matched with the distribution pattern of NP, so that in the east part of the study area, the areas with high industrial density (over 29-40 per Km^2) was significantly higher and even some parts of the eastern area had a density over 37 number per km^2. Moreover, Hot spot analysis showed, with a 99% confidence interval, the east part had the highest industrial density (Fig.5). Also, according to Fig.6, the median of the noise level in the industrial dense area (81.08 dB[A]) was significantly higher than the low-density region (76.51 dB[A]) and the difference was significant (U=50044, P<0.0001). In the industrial zones, the traffic of noisy trucks and big cars for transporting is obviously higher in comparison to other areas, and also the noisy activities of industrial machines could enhance NP in such areas; hence, it is expected that increasing of the industrial land use density is correlated with high NP. In our research, the correlation test confirmed that an increase in density of the industrial land use resulted in an increase in NP (r=0.42, P<0.0001).

Roads are one of the most important factors in the amplification of NP in communities. Some studies have shown the relationship between the increase in road density and the traffic of cars with an increase in L_{eq} (Barrigón Morillas, et al., 2002; Çolakkadıoğlu & Yücel, 2017; Jamrah, et al., 2006). In Tehran, 4 million cars are traveled daily, while it is estimated that the capacity of Tehran's street is only 750000 cars. This issue has caused heavy traffic congestion in the metropolis, resulting in significant NP in this city. In the present survey, due to some limitations, there was no possibility of measuring the number of vehicles traveling on the roads of the studied area; therefore, only the effect of road density on the NP was addressed. In highways, the ever-increasing number of cars and their high speed leads to making more problem for the environment compared to other road types (Alesheikh & Omidvari, 2010), so the weight of 4, 3, 2, and 1 respectively were considered for highways, major roads, arterial roads, and collector roads and then the length of the roads was determined in each cell (Fig.4). As seen in Fig.4, the density of roads is somewhat higher in the east of the region, and in contrast, in the west, the low-density points with a density of 0-5 $m/1000m^2$ are considerably more than the eastern regions of the study area, however, low-density points are observed in the eastern parts. Hot spot analysis showed that although in the eastern region NP is high, there is no hot spot for roads. But in the western region where the NP is low, there is clearly a Coldspot with 90 and 95% confidence interval, indicating that lower road density is likely to result in a reduction of noise levels. Apart from the effect of shape, geometry, and height of buildings in a street, Morillas et al. showed that NP is generally lower in areas with small streets compared to two-way roads because of lower traffic in such streets (Barrigón, et al., 2002). In the present study, the western region has more arterial and collector roads compared to other regions, which leads to lower NP. Fig.6 shows that areas with a high density of road have higher L_{eq} (77.46 dB[A]) compared to areas with lower density (76.59 dB[A]) and the difference is significant ($U=23936$, $P<0.0001$). Also, the results revealed that an increase in road density resulted in an increase in NP ($r=0.73$, $P<0.0001$).

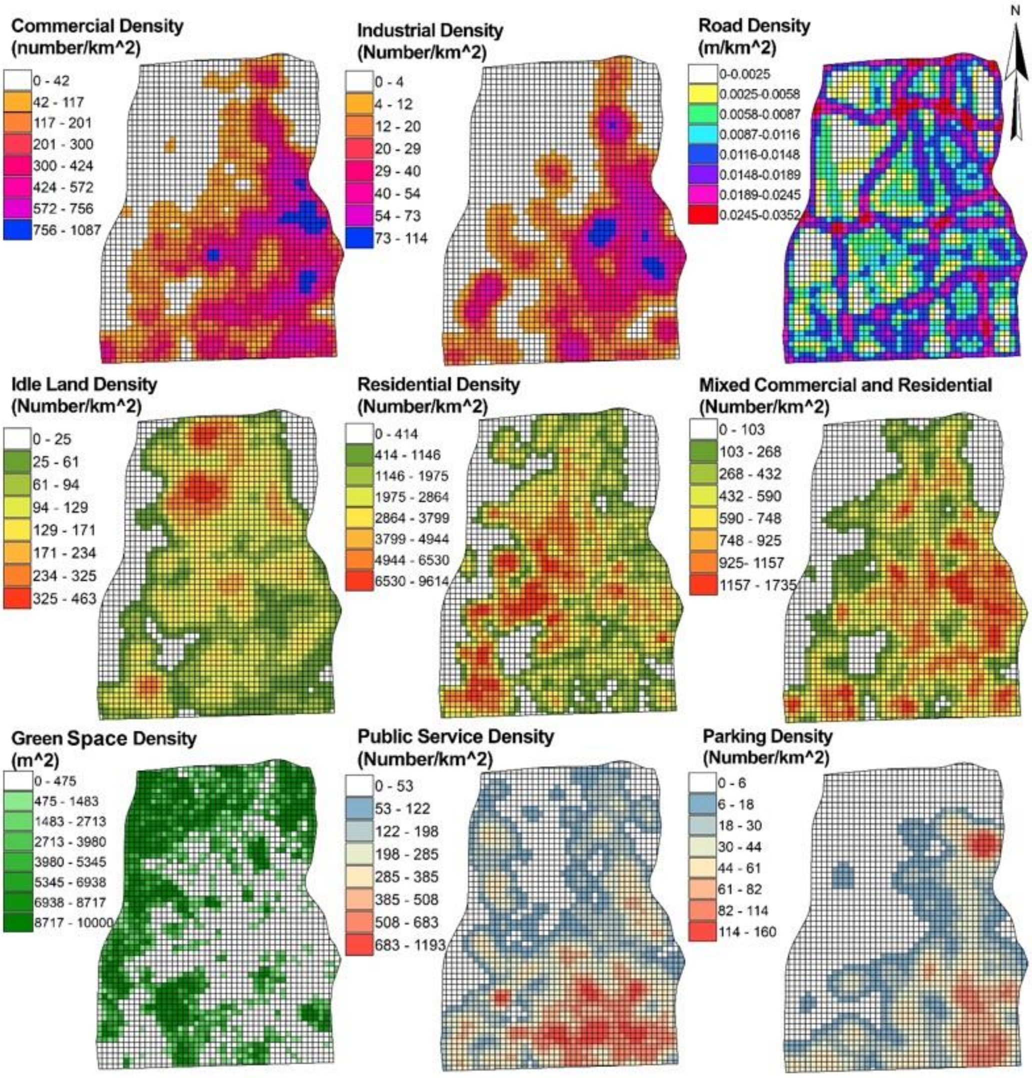

Figure 4. The density map of urban land use for the studied area

In Idle lands, high levels of sound are expected due to construction and demolition as well as the high activities of construction vehicles. On the other hand, in these areas, common urban traffic and buildings density are low, which can also reduce the NP in these areas; Han et al. showed a direct relationship between buildings density and NP (Han, Huang, Liang, Ma, & Gong, 2018). Since no study has been done on the relationship between the density of this type of ULU and NP, in the present study, the effect of this density on NP was investigated. The results showed that the areas in the north and the small area in the southwest of the studied area had a density of over 234 number per km^2 (Fig.4), and in contrast, the areas in the northeastern and western regions had a density less than 25 per km^2. These areas are well featured in Hot spot analysis (Fig.5). Considering the Fig.5, The location of areas with a Coldspot and Hot spot does not match with the pattern of NP in Fig.2. As seen in Fig.6, a small difference between the median of noise levels in Coldspot (76.59 dB[A]) and Hot spot (76.82 dB[A]) areas is observed and this difference was not statistically significant (U=136320.5, P=0.093).

According to Fig.4, the maximum residential density was found in the central and southwest parts of the study area, although some Hot spots were observed in the eastern part (Fig.5). Most residential uses are located in areas with lower NP, which leads to more populations being exposed to lower levels of pollution. The existence of residential areas can also reduce the NP, as the traffic in these areas is generally lower than in commercial and industrial areas. However, the results of the study showed that there was no significant difference between the areas with high density and low density of residential use (U = 189310.5, P = 0.144), and there was no relationship between increasing the density of this ULU and increasing L_{eq} (r = -0.04, P=0.07). Nevertheless, when the residential area is blended with commercial land use, the potential for noise generation will increase because of the growing number of activities and movements in these areas. In a study performed in Turkey, the mixed residential and commercial areas showed the highest NP in comparison with other ULUs (Doygun & Kusat Gurun, 2008). As shown in Fig.4, the mixed commercial and residential densities in the eastern region reach over 1157 number per km^2, although this density is also more dispersed in areas located in the south, southeast, and southwest. Fig.5 also shows that the focus of such coverage with a 99% confidence interval is in the eastern region, which has the highest degree of NP. On the other hand, areas with the lowest density of this type of ULU (with 99% confidence interval) are found in the western part, a small part of the northeast, and southwest; these areas are less polluted. The results showed that there was a significant difference between the median of L_{eq} in the high-density (79.05 dB[A]) and low-density (76.67 dB[A]) mixed commercial and residential regions. Besides, the statistical analysis revealed that this difference was significant (U = 176307.5, P <0.0001). In addition, the correlation between L_{eq} and mixed commercial and residential density was significant (r = 0.26, P <0.0001).

Green land is another ULU that can effectively affect the NP of urban areas. In cities, it has been proven that places where porosity and green space coverage are more developed, the rate of NP is also lower (Han, et al., 2018; Margaritis & Kang, 2017). In addition, soils with higher vegetation are also generally more permeable, and soils with high permeability have more acoustic absorption potential (Han, et al., 2018). The present study showed that a large part of the north, west, and southwest regions have vegetation over 8717 m^2/10000 m^2. Of course, small parts in the south and southeast also had such a density. However, according to Fig.5, the center and east regions with the 95% confidence interval have the lowest vegetation. Considering Figs.2 and 3, it can be concluded that in places with less vegetation, the level of NP is significantly increased. It should be noted that noise reduction is usually done in the green area and the park itself compares to streets around. For example, Margaritis et al. determined the noise in parks in a lower level than the around streets, they concluded that this issue occurred due to the proximity of noise source to the streets (Margaritis, Kang, Filipan, & Botteldooren, 2018). However, it is obvious that green space is a good absorbent for sound due to its surface and porosity characteristics and it is effective in reducing the sound of the environment (Margaritis & Kang, 2017). Also, in areas with dense vegetation, car traffic is usually less, and this can be a factor in reducing NP in such areas. According to Fig.6, areas with higher green space density have a lower median (72.69 dB[A]) of L_{eq} compared to a region with lower density (74.46 dB[A]), which the difference was significant ($U = 170275$, $P<0.0001$). Correlation analysis indicated that there is a reverse significant relationship between the increasing green land density and L_{eq} level ($r=-0.2$, $P<0.0001$).

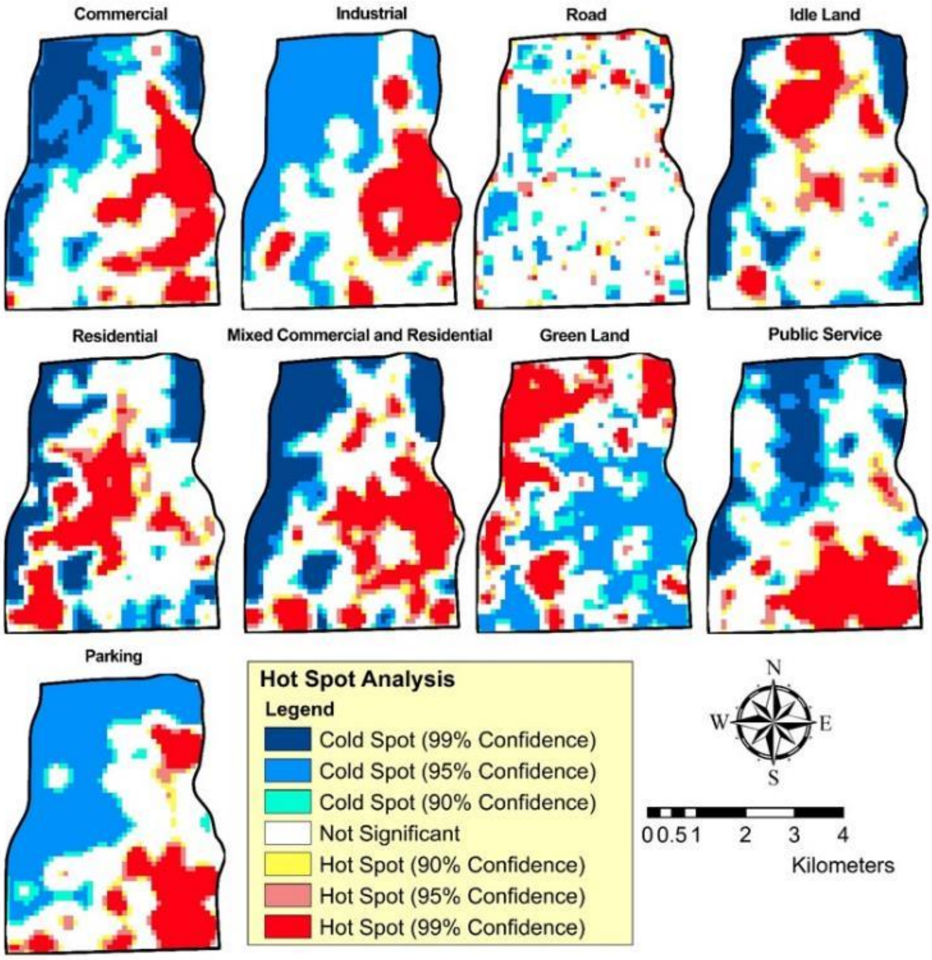

Figure 5. The Hot spot analysis for different urban land uses

As shown in Figs.4 and 5, in the southern and eastern parts of the studied area, the density of public service (such as ministries, government departments, etc.) is high that the density pattern of the land use did not match with the prepared acoustic map of the studied area. Public service centers are usually expected to have higher levels of NP due to high traffic. As seen in Fig.6, the median of L_{eq} in areas with the high and low density of public service were respectively 77.84 dB[A], and 76.91 dB[A], which showed that the pollution rate in Hot spot is higher but there is no significant difference (U=201907, P=0.75) and no relationship was observed between the density and L_{eq} (r=0.01, P=0.56). Car traffic in parking cause an increase in NP in these places and streets around, because traffic is one of the main sources of noise in the urban environment (Guedes, Bertoli, & Zannin, 2011; Jamrah, et al., 2006). The results of the current study indicated that the high density of parking in the eastern and southern parts is more than in other parts. As seen in Fig.4, these areas are the main location of commercial and industrial uses. Fig.5 shows that in the eastern and southeast of the study area with a 99% confidence interval, the number of parking is higher than in other parts. It is of note that the small parts in the southwest were also determined as a Hot spot. As seen in Fig.6, in locations with a high density of parking, the median is significantly higher than the areas with low density (U=143299, P<0.0001). Moreover, the result showed that there is a significant and direct relationship between parking density and L_{eq} (r=0.26, P<0.0001).

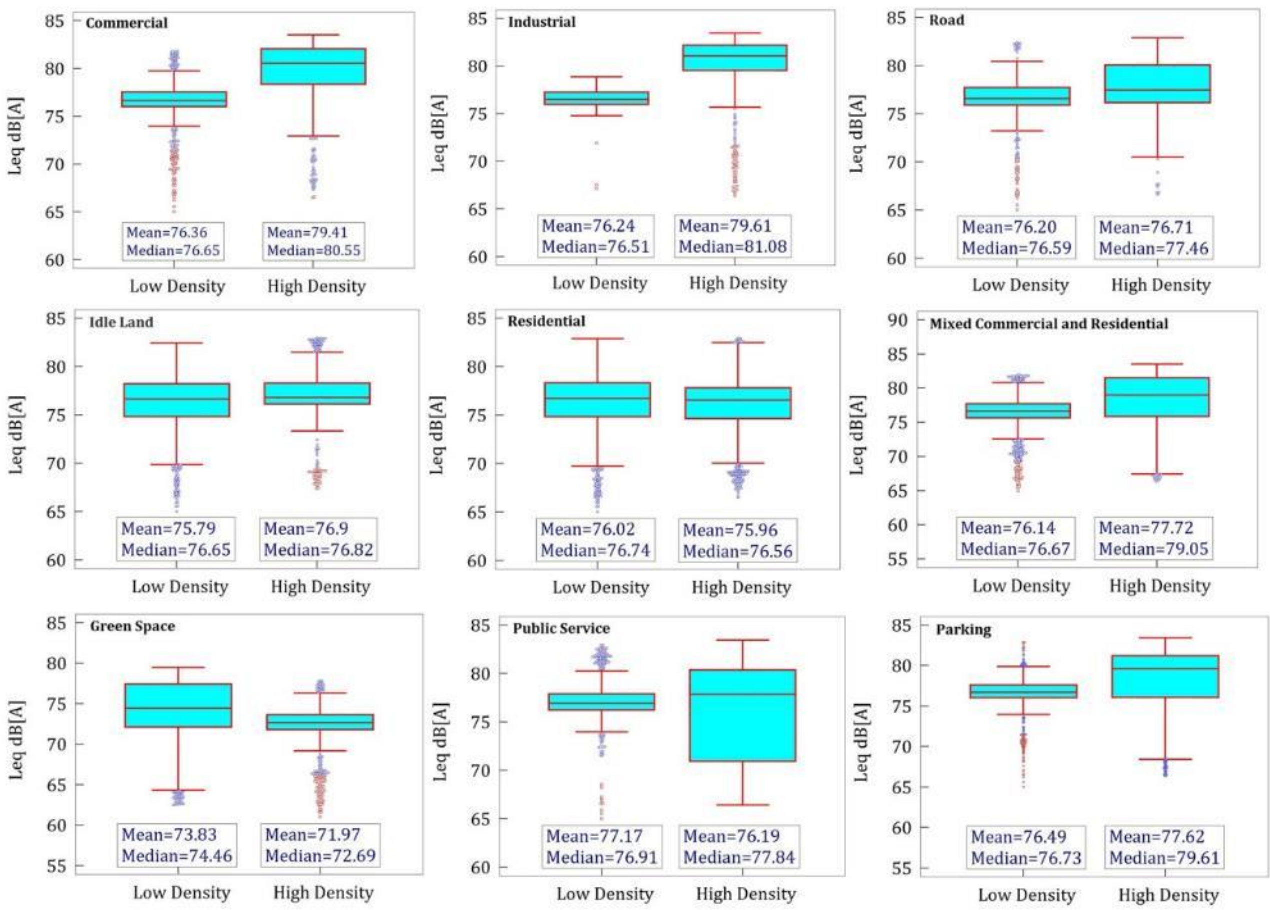

Figure 6. The comparison of L_{eq} in Hot and Coldspot areas

4. Conclusion

In the present study, the acoustic map of district 6 in Tehran was prepared by measuring the noise level in different stations. The result showed that in the study area, the mean noise level was 76.17 dB[A], which is higher than the national and international standards. Moreover, in the afternoon (3-7 p.m.), the noise level (76.46 dB[A]) was higher than that in the morning and noon. The results showed that the east of the study area has higher NP than other areas, which indicates that NP control in this area has a major priority. In addition, the southwest region also has the lowest NP. Moreover, the relationship of ULUs including commercial, industrial, roads, idle lands, residential, mixed commercial and residential, green land, public service, and parking, was investigated with NP. The results showed that in areas with a high density of road, parking, commercial, industrial and mixed commercial and residential land uses, L_{eq} level is significantly high and there is a significant relationship between the increased density of these ULUs and L_{eq}. Moreover, a reverse relationship is observed between the green land area density and L_{eq} and in areas with a higher density of green land, the lower NP was recorded. Besides, to control the NP, the following action is recommended: developing the green lands in areas with high NP (the east part), banning the traveling of noise making cars to the study area, especially in morning and afternoon, developing the standard public transportation system to reduce the traffic, provision of rigorous rules to control traffic and prevent the accumulation of cars on the streets, forcing automobile factories to use low-noise and standard engines, restricting the construction of large commercial and industrial centers in areas where NP is high.

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