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USING GIS TECHNIQUES FOR MODELING OF ANTHROPOGENIC NOISE PROPAGATION GENERATED BY A CHAINSAW IN FOREST HARVESTING

KORIŠTENJE GIS TEHNIKA ZA MODELIRANJE ŠIRENJA ANTROPOGENE BUKE KOJU STVARA MOTORNA PILA PRILKOM SJEČE ŠUMA

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SUMMARY

Noise is an environmental pollution that negatively affects human health and reduces the performance of employees. Forest harvesting activities are one of the working environments where noise effect is intense. The most common equipment used in forest operations is chainsaw whose noise affects not only the operator but also the wildlife in the territory. The noise maps showing noise propagation can be effectively used in evaluating and controlling the noise effects. In this study, it was aimed to measure the anthropogenic noise levels resulting from the chainsaw used in tree felling and to map its noise propagation with SPreAD-GIS (System for Prediction of Acoustic Detectability) which is a GIS (Geographical Information Systems) based noise prediction software. The study was conducted in Karacabey Flooded Forest within the city of Bursa in Türkiye. The results indicated that the average noise level from the chainsaw was above the danger limit (90 dBA) that causes increased physiological reactions and headache on the workers. According to the noise propagation map, the noise exposure of the employees exceeded the warning limit (85 dBA) and the maximum noise level was 95.96 dBA during the harvesting activity. In some parts of the study area, the noise level was 45 dBA or above, causing negative effects on bird species. It can be concluded that the noise maps can be effectively used to determine noise propagation generated by a chainsaw and evaluate the noise effects on the operators and as well as on the bird species in the perimeter.

KEY WORDS: anthropogenic noise, noise propagation map, SPreAD-GIS, chainsaw

INTRODUCTION
UVOD

Technological innovations, industrial developments and urbanization have provided countless important contributions and facilities to human life, but also brought some undesirable impacts on natural resources and ecosystems. Environmental pollution such as air, water, soil and noise pollutions are the leading among these impacts. One of the important elements of environmental pollution is anthropogenic noise, which is caused by vehicles (used in land, sea or air traffic), construction equipment, electrical machinery and other similar factors.

Unwanted and disturbing sounds are called noise. In other words, noise is a group of complex and variable sound, which has more than one frequency component and high-pressure that disturbs human ears (Maraş et al. 2011). The main factors affecting the propagation of noise are the distance to the sound source, the absorption of the envi-

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ronment where the sound is emitted, meteorological parameters (temperature, wind, air movements), the absorption of the ground, the presence of forests and wooded areas, and natural and/or artificial barriers in the environment (Aydın 2015).

Some special units and indicators are used in the measurement and evaluation of sound. The A-weighted sound pressure level (dB or dBA) is the unit of sound pressure in which the middle and high frequencies to which the human ear is sensitive are emphasized. The most commonly used sound levels are A-weighted sound levels in noise control studies. Noise, which affects human health physiologically, physically and psychologically, is an environmental pollution that reduces people's performance in working environment, education and home life. Scientific studies conducted on the subject show that more than 20% of the world population is exposed to noise levels above normal and approximately 60% of the European population is exposed to high noise levels during the day (Rivas et al. 2003).

Within the framework of the sustainability of forest resources, the process of benefiting from the functions offered by forests continues and it is expected that this situation will continue in the face of increasing population. When considering the business objectives of the forest resources, one of the most important purposes is the production of wood raw material. Harvesting operations in forestry is one of the working environments where the noise effect can be intense. Depending on the difficulty of the work and the type of equipment used, the effects of the noise exposure of forest workers and operators vary (Neitzel and Yost 2001, Serin and Akay, 2010). The most commonly used equipment in harvesting operations is the chainsaw, which is used in tree cutting, delimbing and bucking stages in the production of forest products. Studies on this subject have shown that the chainsaw is one of the most critical equipment in terms of noise level as well (Cavalli et al. 2004, Potocnik and Poje 2010).

Potocnik and Poje (2010) investigated the chainsaw noise level during forest harvesting operation and found that in addition to moving away from the noise source, atmospheric absorption and other factors were also effective in the reduction of noise propagation in the forest. They reported that they reached the natural noise level of the forest at 252 m away from the noise source generated by the chainsaw. Melemez et al. (2012), as a result of the health examinations of forest workers in harvesting operations, found that the inner ear nerves of the forest worker were damaged due to the noise of the chainsaw. It was stated that the workers could hear the deep sounds they encountered in daily life, but they had difficulties hearing the high-pitched sounds such as telephone and doorbell rings. Taş et al. (2018) measured the average noise level as 80.18 dBA in a study where the effect of the chainsaw on the operator was investigated. The maximum noise level was measured at the back-cut stage (100.77 dBA) of tree felling operation. Neri et al. (2018) investigated the effect of using electric chainsaw in terms of vibration and noise effects during forest harvesting operation in coniferous forests. After analyzing the noise measurements, they found that the noise level generated by Li-Ion battery saws was between 81 and 90 dBA.

Noise is a pollution element that has an impact on human health, therefore it must be controlled like all other environmental pollution elements. Noise maps showing noise propagation can be effectively used in the assessment and control of the noise impact. The noise map is defined as a numerical model of noise sources (Probst and Huber 2003). They are used to calculate average noise levels in an area, to determine whether the noise is within acceptable limits, and to identify risky areas where employees are adversely affected (Aydın 2015). Barber et al. (2011) investigated the effect of anthropogenic noise caused by energy systems, aircraft and roads in US national parks (Mesa Verde, Grand Teton and Glacier). They developed a noise propagation model with one of the well know GIS based software, called SPread-GIS, by measuring the noise emitted from oil and gas compressor systems located near Mesa Verde National Park. In the model, they found that the noise emitted from 64 compressors was 34.8 dBA in average throughout the park, and 56.8 dBA in the densest area adjacent to the park. The studies conducted on the mapping of anthropogenic noise propagation caused by forestry equipment are rather limited. Proto et al. (2016) examined the modeling of noise propagation caused by harvesting equipment using SPread-GIS software. The measurements were made on the noises caused by the chainsaw during tree cutting, and the tractor and cable logging during the timber extraction from the harvesting unit. They stated that the highest noise emission was realized by the chainsaw.

Knowing that the noise sources and noise levels in a working environment provides important information for determining the effects of noise pollution on different species and ecosystems (Keyel et al. 2017). In a study conducted by Slabbekoorn and Ripmeester (2008), it was stated that the anthropogenic noise that occurs as a result of increasing human activities often interferes with the communication sounds between birds, causing stress in areas such as not being able to receive warning against the predator, not being able to find a partner, and feeding. In a review study conducted by Akay and Acar (2019), how to use SPreAD-GIS program for modeling noise map was described and the main factors affecting noise propagation in forest (i.e. elevation, land use type, temperature, humidity, wind direction and intensity, climate and weather conditions) were evaluated. Kunc and Schmidt (2019) reported that noise is considered as a serious form of environmental change and pollution that negatively affects both aquatic and terrestrial species.

In this study, it was aimed to develop a GIS-based noise propagation model considering the noise emission caused by the chainsaw used in tree cutting stage of a forest harvesting operation in Karacabey Flooded Forest within the border of Bursa province in Türkiye. The noise propagation map was produced by using SPreAD-GIS in order to predict the noise level caused by the chainsaw to which the operator and other forest workers working in the harvesting area are exposed. On the other hand, there are a total of 126 bird species in the Karacabey Flooded Forest. In the study, the effects of chainsaw-induced noise on bird species in flooded forest were also evaluated using the noise propagation map.

MATERIAL AND METHOD
MATERIJALI I METODA

Study Area – *Područje istraživanja*

The study was conducted during tree harvesting operation taken place in Section 52 within the border of Karacabey Flooded Forest. The main land cover types in the flooded forest are terrestrial forest, agricultural land, pasture and sand dune (Akay et al. 2017) (Figure 1). The geographical location of the study area is between 40°23'38 "- 40°21'43" North Latitude and 28°23'02"- 28°52'21" - 28°34'01" East Longitudes. In the study area, the total forest area is approximately 1200 hectares and the average altitude from the sea is 15 m. The dominant tree species in the flooded forest are ash, oak, alder, willow and poplar, and there are pistachio and larch within the territorial forest boundaries. There are 126 bird species identified through field observations in the flooded forest. Most of these birds are resident species that breed in the area during the spring season.

Noise analysis – *Analiza buke*

Noise level measurements were conducted during the harvesting activities carried out in 2019 in the alder stands located in the flooded forest. The noise level caused by the Husqvarna 365 model chainsaw in tree cutting operation was recorded at 1-second intervals using a PCE 430 Class 1 noise meter. A portable meteorology station (TFA Nexus Funk-wet) was used for measuring climate data (Figure 2). Noise measurements were recorded in 1/1 and 1/3 octave bands between 22-136 dBA and 3 Hz-20 kHz frequency range. When measuring the noise level to which the chainsaw operator was exposed, the noise meter was kept close to the operator's ears (30 cm). In the field measurements, it was ensured that there was no other noise source in the working environment in addition to the chainsaw noise. In order to determine the natural noise level, noise measurements were performed during the period when the chainsaw was not operated and no noise source was active in the area. Within the scope of statistical analysis, tree diameters were divided into three classes (small: < 30 cm, medium: 30-34 cm, large: > 34 cm) to investigate the effect of tree diameters on the noise level caused by the chainsaw. The ranges of the diameter classes were determined considering the tree diameter data obtained in the field study. The diffe-

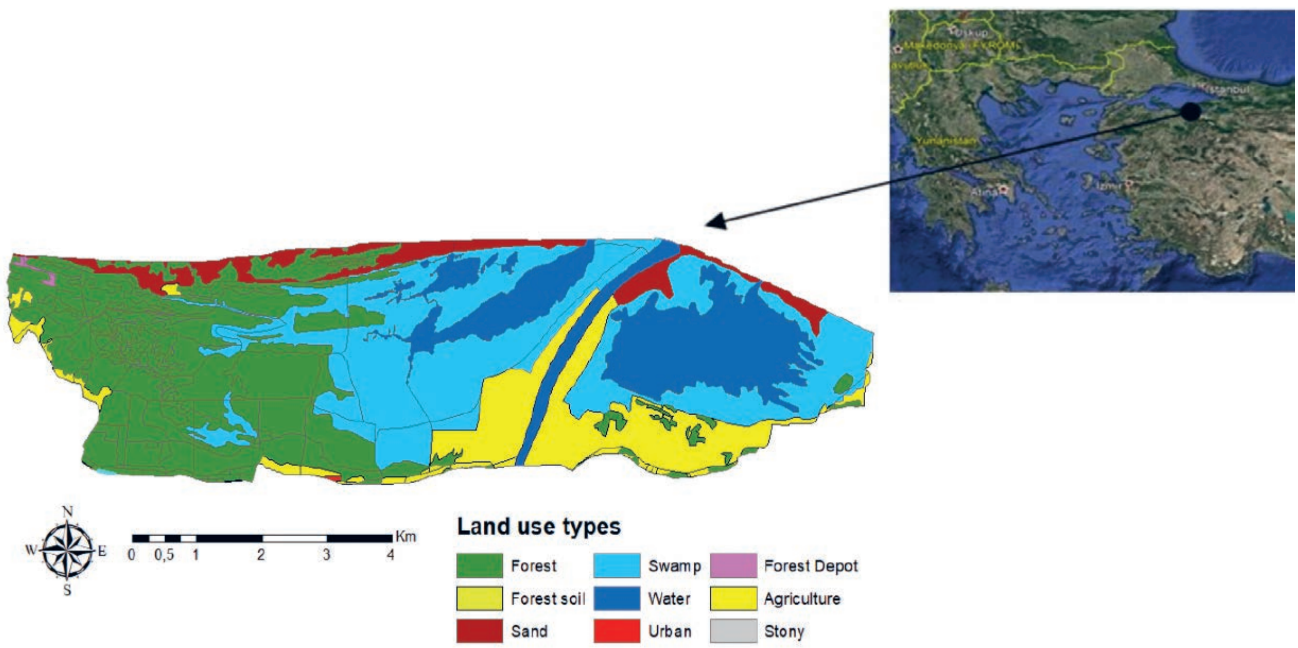

Figure 1. Karacabey Flooded Forest
Slika 1. Poplavna šuma Karacabey

Figure 2. Devices used in the study: a) Chainsaw, b) Noise meter, c) Portable meteorology station
Slika 2. Uređaji korišteni u studiji: a) motorna pila, b) zvukomjer, c) prijenosna meteorološka stanica

rence between the average noise levels according to the diameter classes was examined at the 0.05 significance level with the One-Way ANOVA method.

SPreAD-GIS noise propagation model – *SPreAD-GIS model širenja buke*

The noise propagation map of the study area was developed with the SpreAD-GIS by using the noise values collected from the chainsaw. SPreAD-GIS, an open source software, has been adapted to the ArcGIS 10.4 software environment using ModelBuilder and Python algorithms. SPreAD-GIS takes into account six propagation factors (spherical propagation, atmospheric absorption, land cover and vegetation, wind, terrain structure, predicted noise propagation) to calculate the spatial propagation of noise (Reed et al. 2009). Among the noise propagation factors, the spherical propagation loss is calculated depending on the distance from the noise source. Atmospheric absorption loss is calculated as a function of air temperature, relative humidity and altitude. Losses due to land cover and vegetation are calculated according to the values absorbed by the ground and scattered by the vegetation according to the land cover types (i.e. coniferous forest, hardwood forest, agriculture/grassland/herbaceous, shrubland, bare land, water/swamp, urban). Wind-induced loss is calculated according to the prevailing wind direction, wind speed and seasonal conditions.

The losses due to the terrain structure are calculated according to the decrease in the sound level due to the barrier effect of the hills or ridges on the site. Finally, predicted noise propagation is calculated depending on the difference between the noise emitted from the measured source and the ambient noise level. Thus, it can be determined that the noise emitted from the source can be heard by exceeding the ambient noise and adversely affects the wildlife in the area (Reed et al. 2009). SPreAD-GIS enables the modeling of noise propagation for 1/3 octave frequency bands (400, 500, 630, 800, 1000, 1250, 1600, 2000 Hz) by considering different noise sources. In this way, noise levels from different machines operating simultaneously can be determined and maps representing noise propagation can be produced.

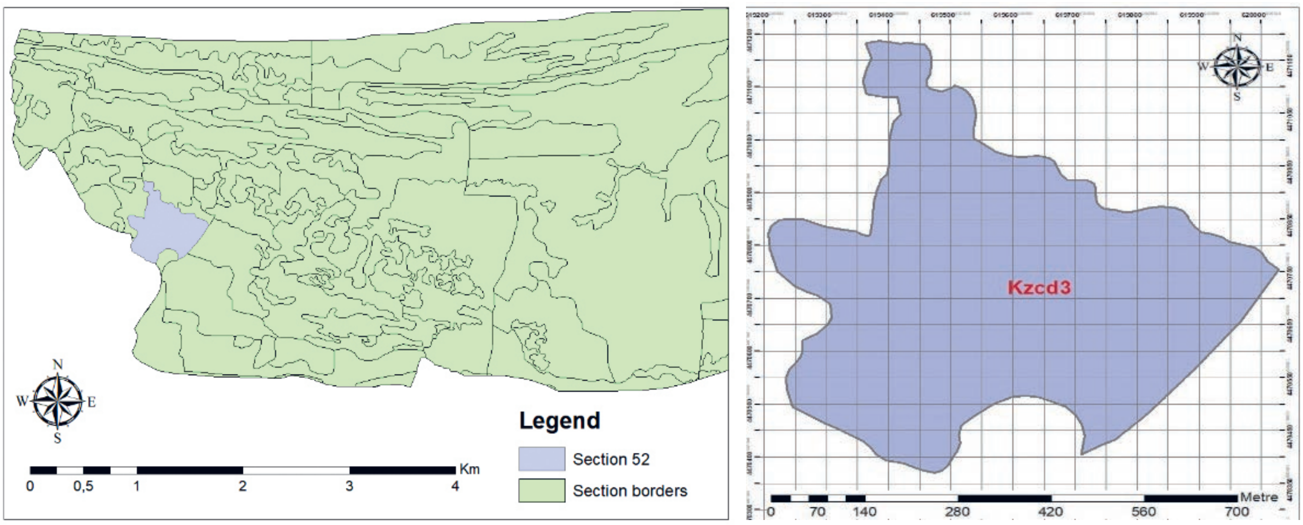

Figure 3. The location of Section 52 (left) and the grids whose centers representing the locations of the noise sources (right)
Slika 3. Položaj odjela 52 (lijevo) i mreže čiji centri predstavljaju lokacije izvora buke (desno)

Model database – *Baza podataka modela*

Before running SPreAD-GIS, the required GIS datasets for the model were obtained and some parameters were determined by field measurements. The database included location of the noise sources, the characteristics of the noise sources, model coverage area (extent), land cover map, Digital Elevation Model (DEM), climate parameters, and the ambient noise conditions in the working environment. The GIS datasets were generated in raster format with 30 m resolution, as required in the model.

Location of the noise sources – *Položaj izvora buke*

The noise source file was developed in the SPreAD-GIS database to represent the locations where the noises are propagated within the study area. Noise measurements were made during the tree cutting operation using a chainsaw in an alder stand in Section 52. The total area of the stand where the measurements were made was 29.41 (about 30 ha) hectares. During the field studies, it was determined that the average length of the alder trees in the area was approximately 25 meters. Considering that the chainsaw operators must work at a safe distance of two tree-lengths during production, the Section 52 was divided into 120 grids with an edge of 50 m. The center point of 120 grids was recorded in the SPreAD-GIS database as locations of the noise source (Figure 2). Since three chainsaw operators work at the same time, noise propagation calculations were made for a total of 40 combinations in the SPreAD-GIS, taking into account three neighboring grids at each time.

Characteristics of the noise sources and model extent – *Karakteristike izvora buke i opseg modela*

SPreAD-GIS allows the user to select from the noise level data of the engines of different machines loaded in the database (Martin et al. 2005). In this study, the weighted noise level values originating from the chainsaw for 500, 1000 and 2000 Hz from 1/3 octave frequency bands were taken into consideration. Another feature of the noise source that needs to be defined is the distance to the noise source. Since the noise meter was placed 30 cm from the operator's ears, 0.30 m was used as the noise source distance. The model extent in SPreAD-GIS represents the spatial scope determined for noise propagation analysis. As the model extent gets larger, the processing time increases in SPreAD-GIS (Reed et al. 2009). In this study, a rectangular shape model extent (4509 m x 14588 m) that covers the Karacabey Flooded Forest was used in order to evaluate the noise propagation beyond Section 52.

Land cover type map and DEM – *Karta zemljišnog pokrova i DEM*

In this study, stand type map of the current forest management plan of Karacabey FMD was used to generate land cover data layer. Each land cover type that falls within the model extent was reclassified into one of the seven land cover types defined in the SPreAD-GIS environment (Table 1). Then, DEM was developed by using the digital contour map of Karacabey FMD.

Table 1. The land cover types and their codes defined in SPreAD-GIS model

Tablica 1. Tipovi zemljišnog pokrova i njihovi kodovi definirani u SPreAD-GIS modelu

Land cover types *Tip zemljišnog pokrova*	Codes *Kodovi*
Coniferous forest *Šuma četinjača*	CON
Hardwood forest *Šuma tvrde bjelogorice*	HWD
Agriculture/grassland/herbaceous *Poljoprivreda/travnjaci/zeljaste biljke*	HEB
Shrubland/maquis *Grmlje/makija*	SHB
Bare land *Gola zemlja*	BAR
Water/swamp *Voda/močvara*	WAT
Urban *Urban*	URB

Climate parameters – *Klimatski parametri*

In modeling the noise propagation using SPreAD-GIS, it is necessary to obtain and enter the climatic parameters for the day and season on which the field measurements are performed. These climate parameters include temperature (°C), relative humidity (%), prevailing wind direction (°), wind speed (km/hour), and seasonal conditions. The model also includes a list to defined seasonal conditions, from which the user can select the seasonal condition that best represents the situation at the time of measurement. Seasonal conditions in the list include "a clear, calm summer day", "a clear, calm winter day", "a clear, windy summer day", "a clear, windy winter day", "cloudy and calm", and "cloudy and windy". In this study, the average temperature, relative humidity, wind direction, and wind speed data were collected during the operation by using portable meteorology station. Seasonal conditions were determined and recorded at the time of measurement in the field.

Ambient noise conditions – *Uvjeti ambijentalne buke*

In the last stage, the ambient noise conditions in the harvesting area were defined and then the areas where the noise originating from the chainsaw can be heard at different frequencies were determined in the model. The ambient noise level values for 500, 1000 and 2000 Hz from 1/3 octave frequency bands were measured as in noise source mea-

Table 2. Statistical summary of noise values for diameter classes
Tablica 2. Statistički sažetak vrijednosti buke za klase promjera

Diameter classes *Promjer razreda*	N *N*	Noise value *Razina buke* (dBA) Average *Prosječno*	Standard Deviation *Standardna devijacija*	Standard Error *Standardna pogreška*	Minimum *Najmanja*	Maximum *Najveća*
Small (<30 cm) *Mali (<30 cm)*	38	99.14	2.94	0.48	89.90	103.30
Medium (30-35 cm) *Srednji (30-35 cm)*	42	99.36	2.69	0.42	93.90	104.60
Large (>34 cm) *Veliki (>34 cm)*	40	99.65	3.24	0.51	93.10	107.90

surements and entered into the SPreAD-GIS. In order to determine the ambient noise level, noise measurement was made for five minutes when the chainsaw was not operated and no noise source was active in the field.

Developing noise propagation maps – *Izrada karata širenja buke*

In SPreAD-GIS environment, spatial propagation model of anthropogenic noise was developed by considering six noise propagation factors and three frequency bands (500, 1000, 2000 Hz). Maps showing the noise propagation at intervals of 5 dBA were produced in raster data format as model outputs. Noise propagation calculations in the SPreAD-GIS were conducted for a total of 40 combinations. In the final noise propagation maps, the combination that gives the highest pixel value among the combinations for each pixel was taken into account. By calculating the difference between the noise arising from the noise source and the natural noise levels in the working environment, the areas where the noise emitted from the source is likely to be heard and the areas where the bird species in the area may be affected were determined. The areas with noise levels of 45 dBA and above, which were determined to affect breeding, stress hormone levels and species richness in bird species, were identified for this purpose (Shannon et al., 2016). In addition, regions where the difference between the noise originating from the noise source and the natural noise difference in the area exceeds 20 dBA and above, which is critical for bird species, were determined (Proto et al. 2016).

RESULTS
REZULTATI

Noise analysis results – *Rezultati analize buke*

Noise level measurements were performed during the tree cutting stage carried out in the alder stands located in the Section 52 in the study area. The results indicated that the average tree diameter was approximately 33 cm and the minimum, maximum and average noise values were approximately 72 dBA, 109 dBA and 99 dBA, respectively. Accordingly, it was determined that the average noise level was more than the danger limit (90 dBA) that causes an increase in physiological reactions and headache. It has been determined that the maximum noise level was above 120 dBA, which can cause continuous damage and disturbance of balance in the inner ear. Within the scope of the study, the effect of tree diameters on the noise level caused by the chainsaw was investigated. Although the results of One-Way Analysis of Variance showed that there was no statistically significant relationship between diameter classes and noise level ($p > 0.05$), it was determined that the noise values increased from the small diameter class to the medium and large diameter class (Table 2).

Model database results – *Rezultati modela baze podataka*

In order to produce the noise propagation map using SPreAD-GIS, firstly, the model database was developed. Noise measurements and climate data collection were performed in four periods for 40 combinations and there were 10 combinations in each period. According to the results, the average maximum noise value and average ambient noise for all noise combinations were found to be 109.3 dBA and 42 dBA, respectively (Table 3). On the other hand, average temperature, relative humidity, wind direction and wind speed were found to be 14 ° C, 66%, 75° and 5.8 km/h, respectively. Seasonal conditions were determined as "clear, calm summer day" for the first period and "clear, calm winter day" for other three periods.

Necessary digital data layers were produced in order to evaluate the effects of the noise locations, terrain structure, and land cover type on noise propagation in the SPreAD-GIS process. The center point of 120 grids generated in Section 52 was evaluated as the noise source in the SPreAD-GIS database. In order to reflect the impact of the terrain structure into the model, DEM was produced for the bo-

Table 3. Data recorded during the noise measurements
Tablica 3. Podaci zabilježeni tijekom mjerenja buke

Periods *Razdoblje*	Combinations *Kombinacije*	Noise Level *Razina buke* (dBA)	Air temperature *Temperatura zraka* (°C)	Air humidity *Vlažnost zraka* (%)	Wind Direction *Smjer vjetra* (°)	Wind Speed *Brzina vjetra* (km/hr)	Ambient Noise *Ambijentalna buka* (dBA)
	1	109.5	20.5	57.6	60	4.9	42.8
	2	110.3	20.5	57.6	60	4.9	42.8
	3	109.8	20.5	57.6	60	4.9	42.8
	4	108.8	20.5	57.6	60	4.9	42.8
First *Prvo*	5	110.2	20.5	57.6	60	4.9	42.8
	6	109.5	20.5	57.6	60	4.9	42.8
	7	109.9	20.5	57.6	60	4.9	42.8
	8	108.5	20.5	57.6	60	4.9	42.8
	9	107.5	20.5	57.6	60	4.9	42.8
	10	109.0	20.5	57.6	60	4.9	42.8
	11	111.2	12.5	77.5	90	4.9	40.4
	12	110.8	12.5	77.5	90	4.9	40.4
	13	109.3	12.5	77.5	90	4.9	40.4
	14	108.5	12.5	77.5	90	4.9	40.4
Second *Drugo*	15	108.3	12.5	77.5	90	4.9	40.4
	16	110.1	12.5	77.5	90	4.9	40.4
	17	111.8	12.5	77.5	90	4.9	40.4
	18	101.0	12.5	77.5	90	4.9	40.4
	19	109.2	12.5	77.5	90	4.9	40.4
	20	110.0	12.5	77.5	90	4.9	40.4
	21	110.1	10.2	63	90	7.1	41.3
	22	112.0	10.2	63	90	7.1	41.3
	23	109.4	10.2	63	90	7.1	41.3
	24	109.5	10.2	63	90	7.1	41.3
Third *Treće*	25	112.8	10.2	63	90	7.1	41.3
	26	110.0	10.2	63	90	7.1	41.3
	27	110.3	10.2	63	90	7.1	41.3
	28	109.1	10.2	63	90	7.1	41.3
	29	110.3	10.2	63	90	7.1	41.3
	30	108.5	10.2	63	90	7.1	41.3
	31	108.7	12.6	67	60	6.3	43.4
	32	108.2	12.6	67	60	6.3	43.4
	33	108.2	12.6	67	60	6.3	43.4
	34	108.4	12.6	67	60	6.3	43.4
Fourth Četvr*oi*	35	108.2	12.6	67	60	6.3	43.4
	36	109.4	12.6	67	60	6.3	43.4
	37	109.7	12.6	67	60	6.3	43.4
	38	108.2	12.6	67	60	6.3	43.4
	39	108.4	12.6	67	60	6.3	43.4
	40	108.4	12.6	67	60	6.3	43.4

undary of model extent. According to the results, the average elevation at the model extent was 12.88 m, and it varied between 0 and 32.05 m from the sea level. Then, land cover type map was produced for the boundary of model extent and each land cover type was transformed into one of the seven land cover types defined in the SPreAD-GIS. The results showed that the land cover type with the largest area was water bodies and swamps (45.17%), followed by hardwood forest (25.42%) (Table 4). Forest soil, sand dune, stony areas and forest depot in the study area were classified under open areas.

Noise propagation maps – *Karte širenja buke*

By using SPreAD-GIS, separate noise propagation maps (30 m x 30 m) were first produced for 40 combinations.

Table 4. Spatial distribution of the land cover types
Tablica 4. Prostorni raspored tipova zemljišnog pokrova

Land cover type *Tip zemljišnog pokrova*	Code	Area (%)
Water/swamp *Voda/močvara*	WAT	45.17
Hardwood forest *Šuma tvrde bjelogorice*	HWD	25.42
Agriculture/grassland/herbaceous *Poljoprivreda/travnjaci/zeljaste*	HEB	14.23
Bare land *Gola zemlja*	BAR	6.07
Coniferous forest *Šuma četinjača*	CON	4.04
Shrubland/maquis *Grmlje/makija*	SHB	3.46
Urban *Urban*	URB	1.59

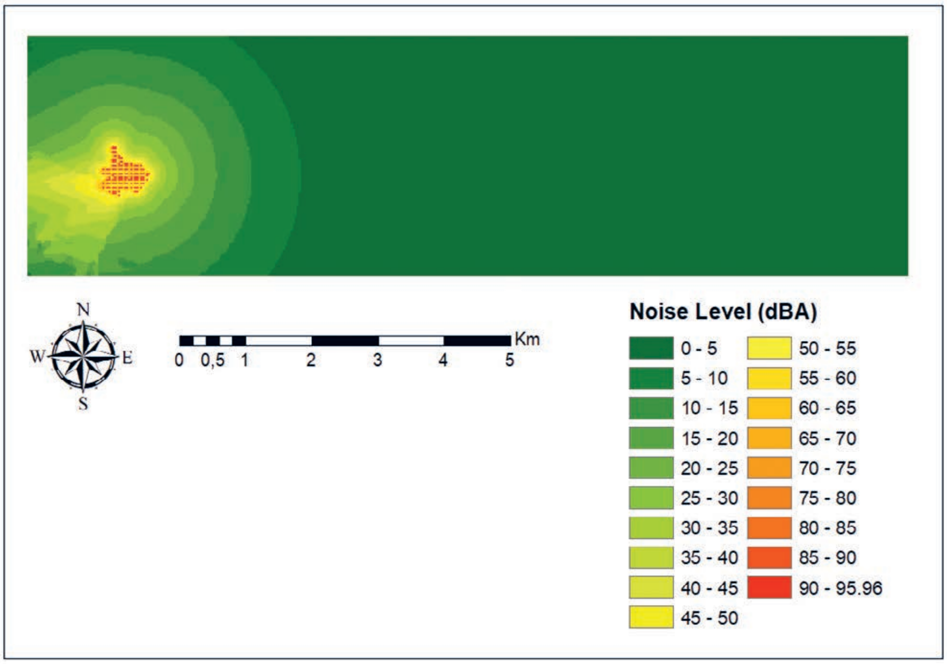

Figure 4. The noise propagation map for the chainsaw-induced noise in the model extent
Slika 4. Karta širenja buke izazvane motornom pilom u opsegu modela

Then, the final noise propagation map was generated considering the combination that gives the highest pixel value among the combinations for each pixel. Figure 4 shows the final propagation map for the chainsaw-induced noise. According to the results, the maximum noise level arising from the chainsaw was determined as 95.96 dBA. This value is above the danger limit (90 dBA) that causes increased physiological reactions and headache.

In order to evaluate the noise exposure of the personnel working around the noise source during the harvesting operation, the areas where the noise is 85 dBA and above (e.g. defined as the warning limit) was detected (Figure 5).

The results showed that the area exceeding the warning limit was 10.62 ha. The areas with 45 dBA and above noise levels that cause adverse effects on bird species were calculated as 63.18 ha (Figure 6). On the other hand, the areas where the difference between the noise originating from the chainsaw and the ambient noise in the working environment is effective on bird species (20 dBA and above) was determined to be 20.61 ha (Figure 7).

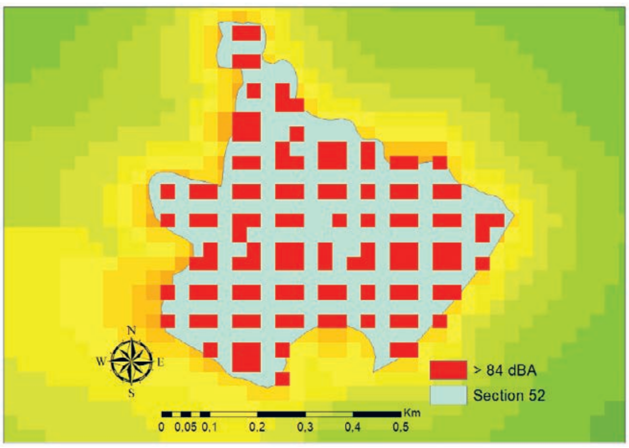

Figure 5. The areas with the noise level of 85 dBA and above in/around Section 52
Slika 5. Područja s razinom buke od 85 dBA i više unutar/oko odjela 52

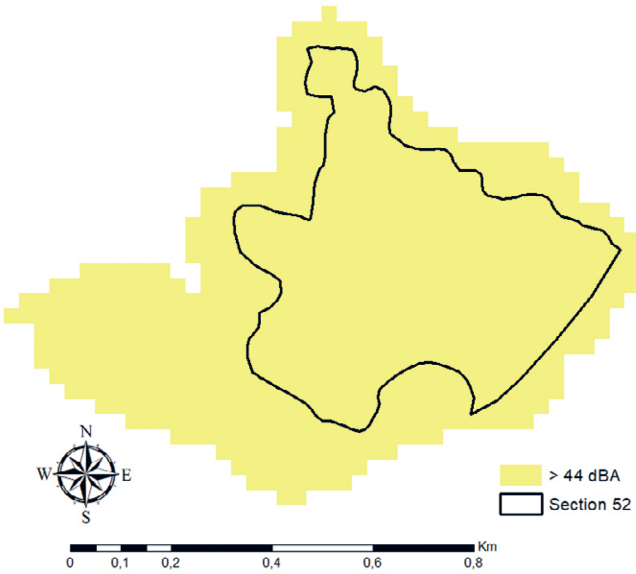

Figure 6. The areas with the noise level of 45 dBA and above in/around Section 52
Slika 6. Područja s razinom buke od 45 dBA i više unutar/oko odjela 52

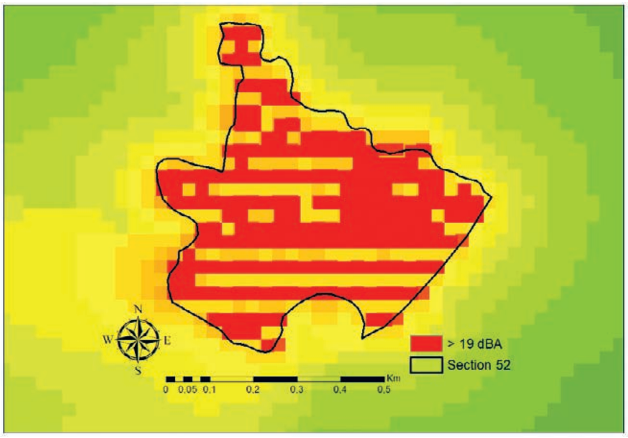

Figure 7. The areas where the difference between the chainsaw-induced noise and the ambient noise was more than 20 dBA in/around Section 52

Slika 7. Područja u kojima je razlika između buke izazvane motornom pilom i buke okoline bila veća od 20 dBA unutar/oko odjela 52

DISCUSSION
RASPRAVA

The graphical display of the noise level measurements for the tree cutting operation with the chainsaw is shown in Figure 8. The results indicated that the average noise level (99 dBA) was higher than the danger limit (90 dBA) potentially causing increased physiological reactions and headache. It was found that this noise level exceeds the tolerance limit values on an hour/day (8 hours) basis (NCR, 1986). In a similar study, Serin and Akay (2008) reported that the average noise level caused by the chainsaw during a tree cutting was also over 90 dBA.

It was also found that the measured maximum noise level (117.9 dBA) was at the dangerous noise level that can cause permanent damage to the hearing ability (Polat and Kırıkkaya 2004). Taş et al. (2018) reported that the maximum noise level was 100.77 dBA in a similar study investigated the noise level of a chainsaw operation. The effect of tree diameters on the noise level caused by the chainsaw was investigate based on three diameter classes (small: <30 cm, medium: 30-34 cm, large: > 34 cm) According to the results, the average noise level on thin diameter class was 99.13 dBA, while it was 99.36 dBA and 99.62 dBA for medium and large diameter classes, respectively (Figure 9). In a previous study conducted by (Tunay and Melemez (2003), it was reported that the noise level measured during tree cutting was 104.3 dBA in medium-sized chainsaws and 111.4 dBA in large-sized chainsaws. In another study, the noise levels caused by electric saws were examined, and the average noise level was measured as 92 dBA when cutting logs with a diameter of less than 30 cm, and 95 dBA for logs above 30 cm (Neri et al. 2018).

The noise propagation calculations were evaluated for 40 combinations and these combinations were taken into account when generating the final noise map. After the noise propagation map was produced, it was classified considering the noise ranges effective on human health (Figure 10). According to the results obtained, it was found that in 135.72 ha of the study area, the noise level was in the range of 36-65 dBA, which can disrupt sleep and resting on people. On the other hand, in the 5.49 ha area, it was in the range of 65-85 dBA, which can cause mental harm and ear disorders. And, in the 10.62 ha area, it was in the range of 85-115 dBA, which can result in mental and physical damage and psychosomatic diseases (Polat and Kırıkkaya, 2004).

The results also indicated that about half of the Section 52 (49.39%) was in the noise range that impairs sleep and rest on humans, while 34.15% of the area was in the noise range that causes mental and physical harm and psychosomatic diseases (Figure 11). The remaining area (16.46%) was in the noise range that can result in mental harm and ear disorders. In a recent study investigating the effect of chainsaw on the operator in tree cutting, Taş et al. (2018) stated that the average noise level (80.18 dBA) was in the noise range

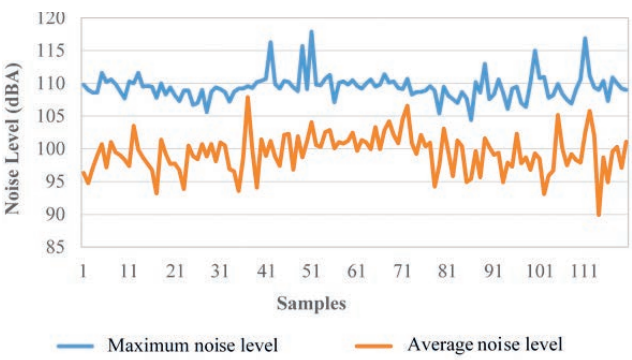

Figure 8. Graphical representation of the measured noise levels in the study

Slika 8. Grafički prikaz izmjerenih razina buke u istraživanju

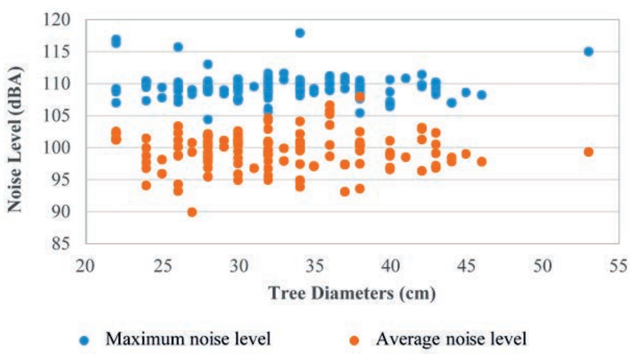

Figure 9. Graphical representation of noise levels according to tree diameter

Slika 9. Grafički prikaz razina buke prema promjeru stabla

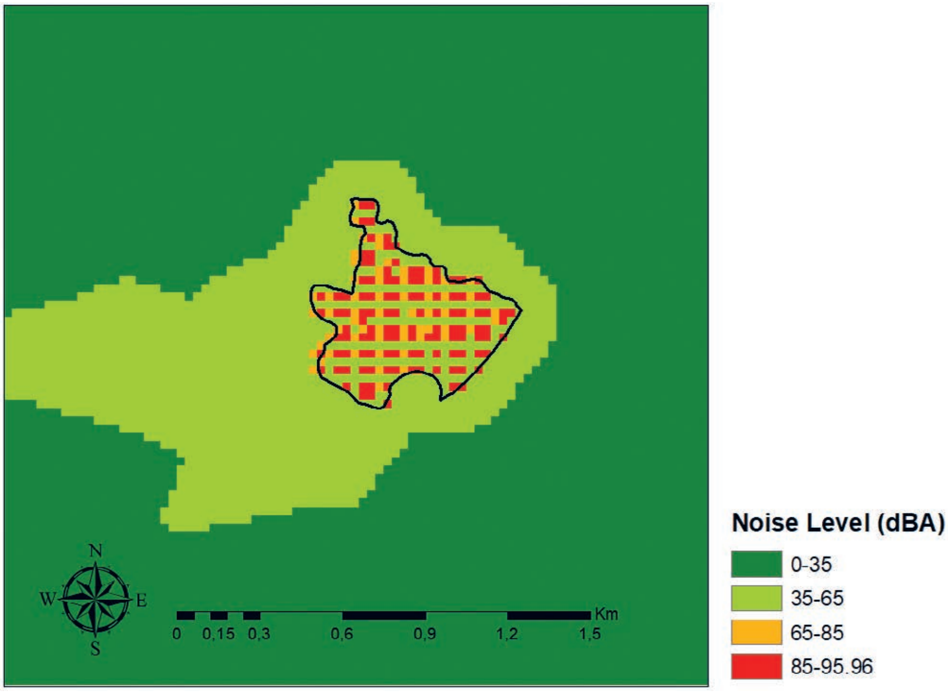

Figure 10. Distribution of noise ranges affecting human health in the study area
Slika 10. Raspodjela raspona buke koja utječe na zdravlje ljudi u području istraživanja

that causes mental and physical harm and psychosomatic diseases. They found that the maximum noise level (100.77 dBA) was in the noise range that can result in mental and physical harm and psychosomatic diseases.

The areas where the noise emitted from the chainsaw may affect the bird species in the study area was determined for Section 52. It was found that the entire section was subject to noise level of 45 dBA (Delaney et al. 1999) and above, which can affect the breeding, stress hormone level and

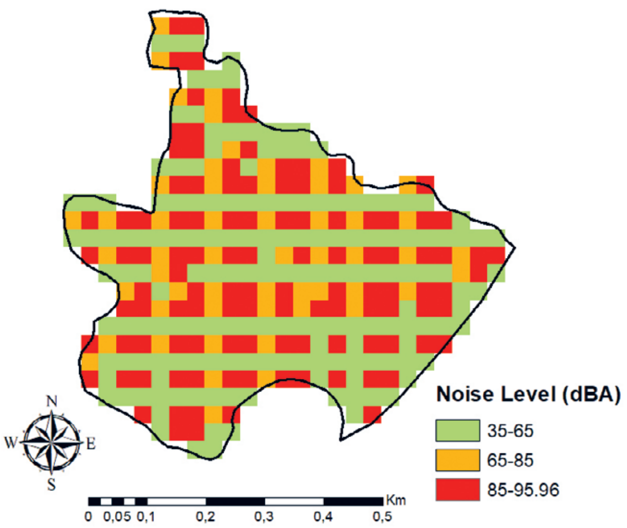

Figure 11. The distribution of noise ranges affecting human health in Section 52
Slika 11. Raspodjela raspona buke koja utječe na zdravlje ljudi u odjelu 52

species richness in bird species. On the other hand, the regions where the difference between the noise from the noise source and the ambient noise exceeds 20 dBA (Proto et al. 2016), which is critical for bird species, was determined to be 18.81 ha. Anthropogenic noise originating from human activities causes adverse effects on birds, especially during the breeding and incubation period, and generates problems in vital functions such as warning against predators and feeding (Slabbekoorn and Ripmeester 2008). It is stated that both aquatic and terrestrial bird species are equally affected by anthropogenic noise (Kunc and Schmidt 2019). It is predicted that 126 resident bird species in the flooded forest subject to the study may be significantly affected by the production activities carried out in the field, especially in the spring, which is the breeding season.

CONCLUSIONS
ZAKLJUČCI

Forest operations in which motorized equipment and heavy machinery are used is one of the working environments with intense noise effect. In this study, the propagation map of the noise caused by the chainsaw used in the tree cutting stage of forest harvesting was produced by using GIS based SPreAD-GIS software. The results showed that the maximum noise level from the chainsaw was above the danger limit (95.96 dBA). According to the results of the noise propagation map, it was found that the noise caused by the chainsaw reached a level that could cause adverse effects on the bird species, especially during breeding and incubation periods, tree cutting with chainsaw should not be coincide with these sensitive periods. In case of necessity, the noise effect should be minimized by using electric powered or Li-Ion battery saws with lower noise levels.

In order to minimize the effect of the noise caused by the chainsaw, it will be safer for the chainsaw operators and other personnel working close to the perimeter to use suitable ear protection equipment. In addition, daily working hours and rest periods should be determined according to the noise levels. In this context, the standard noise exposure times specified in the regulations should be taken into consideration. Timely and correct maintenance and insulation of chainsaws will contribute to the reduction of the noise level caused by the chainsaw. In insulated chainsaws exposed metal parts are isolated from the internal metal motor components with protective insulation.

In addition, considering that the noise from chainsaw changes depending on the type of oil used for chain lubrication, it would be appropriate to evaluate alternative oil types such as vegetable oil and mineral oil to minimize noise exposure. Occupational seminars and trainings should be given to chainsaw operators on the potential impacts of noise on human health and how to prevent these impacts. Employees should undergo periodic health checks, taking precautions to prevent temporary damages from becoming permanent and applying the necessary treatments.

This study has shown that noise propagation maps will make significant contributions in determining the noise level in a study area. However, in future studies, it would be appropriate to evaluate the noise levels arising from chainsaws with different types and power sources. In addition, it will be beneficial to develop noise propagation maps of other harvesting equipment such as harvester, feller-buncher, skidder, agricultural tractor, logging truck. In addition to bird species, other wild animal species affected by anthropogenic noise propagation should be examined in future studies.

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SAŽETAK

Buka je onečišćenje okoliša koje negativno utječe na zdravlje ljudi i smanjuje učinak zaposlenika. Aktivnosti sječe šuma jedno su od radnih okruženja u kojima je buka intenzivna. Najčešća oprema koja se koristi u šumarstvu je motorna pila, čija buka utječe ne samo na operatera, već i na divlje životinje na teritoriju. Karte buke koje prikazuju širenje buke mogu se učinkovito koristiti za procjenu i kontrolu učinaka buke. U ovome radu cilj je bio izmjeriti razine antropogene buke nastale radom motorne pile koja se koristi pri sječi stabala i mapirati širenje buke pomoću SPreAD-GIS programa (Sustav za predviđanje akustične detektabilnosti) čija se procjena širenja buke temelji na GIS-u (Geografski informacijski sustav). Istraživanje je provedeno u poplavnoj šumi Karacabey na području grada Bursa u Turskoj. Rezultati su pokazali da je prosječna razina buke motorne pile iznad granice opasnosti (90 dBA), što uzrokuje pojačane fiziološke reakcije i glavobolju radnika. Prema karti širenja buke, izloženost zaposlenika buci prešla je granicu upozorenja (85 dBA), a maksimalna razina buke tijekom rada iznosila je 95,96 dBA. U nekim dijelovima istraživanog područja razina buke iznosila je 45 dBA ili više, što je uzrokovalo negativan utjecaj na vrste ptica. Može se zaključiti da se karte buke mogu učinkovito koristiti za određivanje širenja buke koju stvara motorna pila i procjenu učinaka buke na operatere, kao i na vrste ptica u okruženju.

KLJUČNE RIJEČI: antropogena buka, karta širenja buke, SPreAD-GIS, motorna pila